THE HETCH HETCHY WATER SUPPLY OF SAN FRANCISCO

REPORT OF M. M. O'SHAUGHNESSY
CITY ENGINEER

TO

THE MAYOR, THE BOARD OF PUBLIC WORKS
AND THE BOARD OF SUPERVISORS
OF SAN FRANCISCO

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CONTENTS

LIST OF EXHIBITS

CITY AND COUNTY OF SAN FRANCISCO

DEPARTMENT OF PUBLIC WORKS

BUREAU OF ENGINEERING — CITY HALL

March 25, 1916.

To the Honorable, the Mayor, the Board of Public Works and the Board of Supervisors of the City and County of San Francisco.

GENTLEMEN:

I hand you herewith my progressive report on the Hetch Hetchy Water Supply project.

The Hetch Hetchy Water Supply is a most stupendous enterprise and in its magnitude and its importance to the City of San Francisco, is second only to the rehabilitation of the City after the disaster of 1906. The work has been well begun and to insure its completion in a satisfactory and economical manner, it is essential that careful study be given to all features of the project by public officials in all departments of the City government and by interested citizens, so that the most effective co-operation can be had in the successful execution of this undertaking.

In this report will be found a broad review of the project as a whole, and for purposes of comparison, there is also given a brief description of two other important American water supply developments of recent years.

A detailed statement of work done during the past year and a program for its continuance and for the initiation of new work is given. The recommendations for future work have been very thoughtfully considered and it is strongly urged that all appropriations requested for this year's work be made available at once.

Respectfully submitted,

M. M. O'SHAUGHNESSY,

City Engineer.

REVIEW OF
THE HETCH HETCHY WATER SUPPLY PROJECT

A substantial amount of preliminary work has been done on the construction of the Hetch Hetchy Water Supply of San Francisco during the past year, and considerable additional work is necessary before any of the vital permanent parts of the system can be commenced. The changes in the membership of the governing body of the city and in the personnel of the various committees make it pertinent at this time to set forth a broad review of all the work already done and the general plan under which the future construction, both preliminary and permanent, will be prosecuted.

Enthusiastic amateur critics among the public at large are prone to demand tangible results at the very inception of any great public improvement and to indulge in unbalanced criticism, with a lack of knowledge of the facts, at the expense of the officials in charge when they find that much time must often elapse between the voting of bonds and the commencement of active work on a great project. Undertakings of such magnitude as our great mountain water supply have to be properly considered and balanced in every detail. In every similar successful enterprise there has been a preliminary period of organization and preparation which has often been the most difficult part of the whole project.

Further, after construction has been started, there is a certain minimum time in which different portions of the work may be finished, which is generally determined by the maximum number of workmen who can be economically employed on certain units of the system.

Types of Construction

The Hetch Hetchy aqueduct will be a combination of pipe lines and tunnels. Pipe lines can be divided into sections of any size desired; the work on each section is in the open and can in general be prosecuted almost as fast as the materials can be delivered to the job, so that progress on this class of construction is quite rapid. The speed of tunnel construction, however, is absolutely limited to the rate of progress of the men working on each heading, whose number cannot be increased because there is no room for more. On a concrete dam, progress is limited by the space available for the construction plant. All these things must be considered together and a program arranged under which the divisions of the project requiring the longest time for construction will be begun earliest, the other divisions following in order so that all will be brought to completion as nearly as possible at the same time.

The relation between preliminary work and permanent construction on such a project as the Hetch Hetchy Water Supply, and the time required for completion, are best realized after comparison with other similar works. In recent years there have been only three water supply developments in America of a size and nature to compare with the Hetch Hetchy. They are the Metropolitan

Water Supply System, shared by Boston and neighboring cities, which has been in successful operation for some years; the Owens River supply of Los Angeles, recently completed and partially put in operation; and the Catskill development of the City of New York, now nearing completion.

THE LOS ANGELES AQUEDUCT

This entire development, from the Owens River intake to the terminal receiving reservoir near Los Angeles, has a total length of 223.4 miles, classified as follows:

Open unlined canal	23.8	miles
Lined uncovered canal	38.9	"
Lined and covered conduit	97.7	"
Tunnels	42.9	"
Steel siphons—pressure	9.4	"
Concrete siphons	2.6	"
Concrete flumes	0.2	"
Reservoir length	7.9	"
Total	223.4	miles

The aqueduct is designed for a capacity of 260 million gallons daily, which can be used in transit to develop electric power averaging 49,000 horsepower. The cost to date is about $27,000,000, and water is being delivered, but no power has as yet been commercially developed.

In September, 1905, the matter of bringing Owens River water to Los Angeles was presented to the people, who by a 14-to-1 vote passed a bond issue of $1,500,000 for the purchase of lands and the preliminary investigation. A second bond issue was ratified in June, 1907, and in November, 1907, active work on permanent construction was begun on one division. At the end of the year 1908, six divisions were under way; in 1909, nine divisions; in 1910, ten, and in 1911, the entire line of eleven divisions. On April 1, 1910, the work was estimated to be 65% complete, and it was then predicted that the aqueduct would be finished by May 1, 1912. In November, 1913, the first water was delivered at the terminal point and the aqueduct was turned over to the Board of Public Service Commissioners for operation, though much work remained (and still remains) to be done on hydro-electric power development, and no power has yet been marketed from the completed system.

From the inception of the aqueduct plans the project had the fullest possible co-operation of the officials of the United States Government and all necessary legislation was put through Congress with little or no opposition.

What the Chief Engineer of the Los Angeles Aqueduct Says

Mr. Wm. Mulholland, Chief Engineer of the aqueduct, gave a very brief general view of the construction in an address before the League of California Municipalities, reported in "Pacific Municipalities," issue of November, 1915. page 542:

"We went to work on the scheme, and in seven years we finished it—that is, from the time of the beginning of construction. We turned the first shovel-

ful of dirt in 1907, and we had the celebration of the completion of the aqueduct, although it was not totally completed—there were some tunnels that had to be done, but they could be by-passed by turning the water around them—in 1913—that made six years, and we were really seven years on the job, because there was a year's more work that had to be done afterwards.

". . . The aqueduct really was a very bold project in many ways. We had to pass through a country that was wholly uninhabited, that was forbidding in the extreme. We had to lay 320 miles of water pipe, and water construction. We had to build power lines, and roads, four or five hundred miles of roads, trails, telephone lines. We spent altogether $4,000,000 in getting ready for the job. That was the most trying time in the existence of the work. We were all fearful that some diligent taxpayer might arise and say, 'Here, you have spent $4,000,000, and you haven't done a dollar's worth of work yet,' which would have been absolutely true. So far as the actual construction of the aqueduct was concerned there had not been a dollar's worth of work done when we had $4,000,000 spent. You can imagine that I was in a timid state of mind. It was always impressed on me, all through my life, that it paid to get a good 'ready' on. I didn't want to see the work start until it was completely ready. And you could not properly start without doing that. You had no transportation systems. There was nothing but miles and miles of desert waste to go over. There was no water, no power, we built our own cement plant on account of the excessive transportation cost."

Report of the Board of Consulting Engineers

After the first bond issue, more than a year was spent in preliminary investigations and surveys, and then a board of consulting engineers was appointed to examine the ground, review the work done, estimate the cost of construction and time required, and suggest changes. This board spent six weeks on its work and submitted a report dated December 22, 1906, which is printed in full in the First Annual Report of the Los Angeles Aqueduct. The following excerpts contain much that is of general application to all great water supply works:

"Modifications of Plan:

"In a work of this magnitude and on such bold lines, many trial routes must of necessity be surveyed, their cost estimated and their advantages compared before the final line for construction is laid down. In an aqueduct and reservoir project more trial lines are needed than on a railroad project because of the necessity of following a gradient along which water will flow with velocity rapid enough to prevent sedimentation and not so rapid as to produce scour, and because of the importance of distributing the fall so as to lessen the diameter and cost of the more expensive portions of the work, and adapt to each type of ground the type of conduit best suited for utilizing the natural resources of the neighborhood in material for concrete and masonry.

"Although it is now certain that the best general line of location has been reached, many local variations are still possible, and six or more months of

further study by your engineers may well be devoted to this matter of final location."

"Time Required to Complete the Project as Outlined

"In our opinion five years is the minimum time in which the projected works can be completed so that water from the Owens River can be delivered into the San Fernando Valley.

"The controlling feature in determining the time is the Elizabeth Lake tunnel, the longest on the line, which will be about 25,000 feet in length, exclusive of the deep approaches at its two ends, and which must be driven from only four headings, two of which will start from a shaft about 350 feet in depth, located in the valley near Elizabeth Lake. It will take the larger part of a year before work can be actively begun on the tunnel proper, and about four years more for the excavation of the tunnel and for lining it throughout with concrete masonry.

"Five years also appears as little time as may be prudently reckoned for the completion of the long series of shorter tunnels in the rugged country between Little Lake and the north end of the Antelope Valley section of the conduit.

"Due consideration of economy dictates that work should not be begun on these northerly tunnels until the railroad pertaining to the aqueduct has been extended far enough north to give convenient access to them, and until suitable power plants have been provided. . . .

"While these northerly tunnels are all of them short in comparison with the Elizabeth Lake tunnel and any one could be constructed much more quickly, there will be economy in avoiding unnecessary duplication of plant for carrying them all on simultaneously, and five years from the present time appears little enough time to allow for completing them all."

"Engineering Organization.

. . . . . .

"The work of building a water-tight and durable aqueduct, erecting safe and stable dams, and of constructing the great steel siphon pipes which will be required is of a far more exacting character than a railroad construction.

"The Los Angeles Aqueduct is a work of such magnitude and extends over so many miles of territory somewhat remote from the base of supplies, that it will be a physical impossibility for the chief engineer and the principal assistant engineer to be upon all parts of the work frequently enough to give the quick decision that is necessary for overcoming obstacles. *It will, therefore, be essential to have in the field engineers of proved executive skill and resourcefulness, who are expert in the line of work which they are to supervise. We recommend substantially the plan of organization which has been successfullly adopted upon the Metropolitan Water Works of Massachusetts and upon the New York Aqueduct which is now being prepared for construction.* On the Metropolitan Water Works, representing about the same cost as the Los Angeles Aqueduct, but covering an extent of not more than sixty miles, and where all parts of the line were easily accessible, five of these skilled engineers, known as department engineers, were employed, and all of them were men

who had had sufficient experience to enable them to fill a position as chief engineer upon an important work.

"In New York, although the work has not yet advanced beyond the preliminary stage, five department engineers of this high grade are now employed. Consulting engineers were also connected with both of these works continuously.

"Our recommendation is, therefore, that under the chief engineer and the principal assistant or deputy chief engineer the work be divided into several main departments, each placed in charge of a department engineer having his principal office near the work which he is to supervise.

"In order to secure suitable men for these positions, *it will be true economy to pay liberal salaries sufficient to attract men from other work in these times when the abler engineers are all busy,* rather than to take men of less ability and unproved executive skill.

"There should be an efficient staff at headquarters to prepare designs for the work of construction and to make the necessary studies and investigations.

"The above recommendations are founded upon the experience on similar large aqueducts where most of the work has been done by contract. If this work is to be done in large part by day labor a somewhat different organization would be required, including men of special skill in several branches of the work."

Relation of Preliminary and Overhead Costs to Total Cost

Cost accounts were kept in great detail. The following summary of cost of construction to May, 1914, is taken from a report by O. E. Clemens, who supervised the cost accounting:

Waterway construction, covering the direct cost of all features of the aqueduct which are permanently useful for the conveyance of water, but excluding the cost of preliminary and auxiliary construction		$15,942,489
Auxiliary expense, covering cost of water supply for construction purposes, roads and trails, buildings, telephone lines, power distribution lines, equipment and miscellaneous items		3,777,708
Total cost comparable to total cost of preliminary construction and payments on contracts if the work had been done by contract instead of by day labor		$19,720,197
Overhead expense, covering—		
preliminary engineering	$399,588	
field administration	371,242	
general office	730,200	1,501,030
Total waterway cost to May, 1914		$21,221,227
This does not include lands and rights of way, cement mill and additional construction for power purposes, which, together with the expenditures since May, 1914, bring the total at the present time up to about		$27,000,000

Organization of Force

The organization of the engineering force and its auxiliaries during the construction period is shown diagrammatically on Exhibit "L," attached hereto.

The work was done almost entirely by day labor.
The maximum number of men employed was 3814.

THE CATSKILL WATER SUPPLY OF NEW YORK CITY

This project is of particular interest in comparison with the Hetch Hetchy, as in many features it resembles the Hetch Hetchy project as now planned. Its high concrete dams, tunnels, cement lined pipes, submerged pipes, and many details, afford invaluable lessons to be observed in the design and construction of the Hetch Hetchy works.

The Catskill development adds to the water supply of New York City 250,000,000 gallons daily from the watershed of Esopus Creek. This water is impounded in the Ashokan Reservoir, whose available capacity is 128,000,000,000 gallons. From Ashokan the water goes through the Catskill Aqueduct 75 miles to the Kensico Reservoir. This reservoir stores 29,000,000,000 gallons. Its function is to insure the continuity of the supply to New York if the aqueduct between Ashokan and Kensico is put out of service by accident or otherwise. The aqueduct continues 15 miles to Hill View equalizing reservoir, just outside the city line. After passing through this reservoir, the water enters the City Tunnel, 18 miles in length, 200 to 750 feet below the ground surface. The water is taken from the tunnel into the distributing pipe system through 22 shafts. From the terminal shaft in Brooklyn, a steel pipe extends 5 miles northeasterly, and another line crosses the harbor entrance and ends at a distributing reservoir on Staten Island.

No power development is included in the project.

The yield of the watershed directly tributary to Ashokan Reservoir is 250,000,000 gallons daily, but the supply is to be increased by the diversion of 250,000,000 gallons daily additional of water from the adjacent Schoharie watershed, and therefore the aqueduct was built to carry 500,000,000 gallons daily. The Schoharie development, comprising a great reservoir and a tunnel 16.7 miles in length, is to be begun shortly, and will require eight years' time for construction.

The aqueduct consists of—

55 miles of cut-and-cover aqueduct, 17′ x 17′-6″.
14 " " grade tunnels, 13′-4″ x 17′.
17 " " pressure tunnels, generally 14′ in diameter.
6 " " steel pressure pipe siphons.

Total 92 miles of aqueduct from Ashokan to Hill View Reservoir.

18 miles of "City Tunnel," a pressure tunnel 15′ to 11′ in diameter
14 " " steel and cast iron pipe, 36″ to 66″ in diameter leading from the end of the City Tunnel.

Preliminary Work and Progress of Construction

The first report of the series which led up to the adoption of the Catskill project was made in 1897. Between 1897 and 1905 a great deal of thought was given to the planning of this development by some of the most eminent engi-

neers in America. In August, 1905, the present Chief Engineer, J. Waldo Smith, began his duties. In October, 1905, the report of the Board of Water Supply Commissioners, recommending the development, was submitted to and approved by the Board of Estimate and Apportionment, and in May, 1906, the approval of the State authorities was obtained. Shortly after this time the detail surveys, experimental work to determine the best types of construction for various features of the work, exploratory borings and shafts, design of structures, preparation of specifications, and purchase of real estate were begun. This "preliminary work" extended almost to the end of the construction period, as the experience gained on work in progress was taken into account as bearing on work not yet begun.

The program of construction was laid out as closely as possible so as to bring all parts of the work to completion at the same time. Work on the first contract was begun in June, 1907, and 1911 was the year of maximum expenditure ($25,949,000), but the city tunnel was only commenced in 1911. The first Catskill water was delivered into the distribution pipes of New York City December 27, 1915.

The work described is now nearly completed, at a cost of over $136,000,000, divided approximately as follows:

	Amount.	Per Cent of Total.
General administration	$ 1,500,000	1.
Police Bureau	2,000,000	1.5
Engineering Bureau—		
Salaries, supplies and equipment	13,500,000	10.
Real estate and taxes	19,000,000	14.
Contract payments	100,000,000	73.5
	$136,000,000	100.

The annual disbursements are shown by the upper diagram on Exhibit "M."

The construction of the Schoharie reservoir and tunnel will cost $26,000,000, raising the total to $162,000,000.

These figures do not include interest during construction.

Organization

The Board of Water Supply consists of three commissioners appointed by the Mayor. It has had general supervision over the entire Catskill project, from the inception of the work to the present time. Its forces are divided into Administration, Real Estate, Police, Claims and Engineering Bureaus. In the first four bureaus are the secretary, the auditor, the chief clerk, the examiner of real estate, taxes, and legislation, the superintendent of Board of Water Supply Police, and the chief of the Bureau of Claims. The Engineering Bureau is composed of five departments: The Headquarters Department, in which the mapping, designing, preparation of specifications, etc., were carried out; and four departments each of which embraces a main division of the construction work. A department engineer is in general charge of all work in his department, which is subdivided into divisions and sections.

The engineering organization is shown diagrammatically on Exhibit "N," attached, and the fluctuation of the engineering force on Exhibit "O."

The Board exercised strict sanitary control over the contractors' camps, enforcing its regulations by means of its Police Bureau, which was also charged with the duty of maintaining order in the camps and on the work and protecting the inhabitants of the surrounding country against any bad characters who might be employed. The necessity for such control is seen from the fact that some of the camps assumed the proportions of good-sized towns. That at the Ashokan reservoir had a maximum population of 4500, of whom 3000 were employed on the work. The camp at Kensico dam had accommodations for 1200 persons.

The maximum number of men in the Board of Water Supply organization and the number employed at present are shown in the following table:

BOARD OF WATER SUPPLY FORCES

	Feb. 1, 1916	Maximum
Commissioners	3	3
Administration, Real Estate and Claims Bureaus	43	66
Police Bureau	70	387
Engineering Bureau—		
Chief Engineer and staff	11	13
Headquarters Department	124	260
Reservoir Department	148	236
Northern Aqueduct Department	67	630
Southern Aqueduct Department	113	318
City Aqueduct Department	110	209
Total, Engineering Bureau	573	
Total, Board of Water Supply	689	
Engineering Bureau; maximum force at any one time		1,348

The greatest number of men included in the contractors' forces on active field work at any one time was 17,243.

The variation in the forces from the beginning of the work to the middle of 1915 is shown by the lower diagram on Exhibit "M."

THE HETCH HETCHY DEVELOPMENT

Like the two great engineering works already described, the Hetch Hetchy water supply project for San Francisco has been years in taking definite form. Unlike them, however, it has had to contend with strong opposition from powerful interests, both within and without the city whose growth is to be made possible by this vitally necessary addition to its resources.

The Progressive Development of San Francisco's Water Plans

When the present charter of San Francisco was framed, provisions were incorporated looking toward municipal ownership of the water supply. The charter went into effect in 1900 and in that year, by direction of the Board of Supervisors, the City Engineer began an investigation of "available sources" of water supply. It was decided that the Tuolumne River presented the most

advantageous possibilities, and in 1901 and 1902 surveys, studies and cost estimates were made, the results of which were embodied in a report by the City Engineer, C. E. Grunsky, dated July 28, 1902, presenting plans and estimates for a water supply system using Hetch Hetchy Valley as a reservoir site, with Lake Eleanor as a reserve for the future. The system was planned for an initial development of 60,000,000 gallons daily, capable of increase to 160,000,000 gallons daily. The aqueduct to San Francisco was to consist of 28 miles of open canal, 13 miles of tunnel, and a double line of 48-inch pipe 141 miles long, the total length of aqueduct being 182 miles. The water was to flow by gravity to the west side of the San Joaquin Valley, and was then to be pumped over the Coast Range by means of the power generated in the Sierra water drops. No power was available for other uses, and furthermore a large steam auxiliary was necessary to insure continuity of service in case the supply of electric power was interrupted.

In 1908 a revised plan was submitted by City Engineer Marsden Manson for an immediate development of 60,000,000 gallons daily and ultimate increase to 200,000,000 gallons daily. The essential difference from the Grunsky plan was the utilization of Lake Eleanor first, due to U. S. government restrictions in the Garfield permit, and Hetch Hetchy later. Mr. Manson afterward made several important changes in the scheme, increasing its ultimate capacity and power possibilities, so that in 1911 its principal features were as follows:

Lake Eleanor reservoir to be developed first, with a portion of the flood waters of Cherry Creek diverted into it; Hetch Hetchy to be developed later.

Main aqueduct to consist of:

27 miles of cut-and-cover conduit, capacity 300,000,000 gallons daily (part 365,000,000 gallons daily for the sake of increasing power).

30 miles of tunnel, same capacity as canal.

124 miles of double pipe line, each pipe 50 inches in diameter; capacity of the two pipes, 60,000,000 gallons daily.

181 miles total length of aqueduct.

40,000 horsepower to be developed and a large part of this power used for pumping, as in the Grunsky plan.

From 1908 to 1912 surveys were made for the canal lines, but difficulties with governmental authorities, due to private corporate interests persistently opposing the municipal enterprise, were so great that no progress towards actual construction was made. No similar interference was encountered in the Los Angeles and New York projects.

In 1910 John R. Freeman, a distinguished hydraulic engineer with broad experience, was engaged as consulting engineer by the City to make new plans and formulate a report which should summarize and supplement all knowledge already gathered pertaining to the extension of the City's water supply and also fortify the presentation of the City's application for the Hetch Hetchy grant. The plan presented in this report, dated July 14, 1912, providing for an ultimate supply of 400 million gallons per day from the Tuolumne watershed, is in its essentials the same as that on which work is now being carried forward, with certain necessary modifications due in part to the restrictions

of the congressional grant (known as the "Raker Bill") and in part to more mature study of the engineering and economic problems involved. The rights in the Hetch Hetchy and other public lands desired by the City were at last granted by act of Congress in December, 1913.

The plan as now proposed is shown by the maps and profile, Exhibits "A," "B" and "C," attached. The Hetch Hetchy will be the first reservoir site utilized, and the Lake Eleanor and Cherry Valley dams will be built later, as the necessity for increasing the water supply beyond the capacity of the Hetch Hetchy watershed arises. The aqueduct in the initial development will consist of 88 miles of pipe five to five and one-half feet in diameter, and 66 miles of tunnels ten to ten and one-half feet in diameter, a total length of 154 miles to the county line of San Francisco. After the first 19 miles of aqueduct from Early Intake is completed, the water will be dropped 1300 feet through an electric generating station at Moccasin Creek, where an average of 66,000 horsepower will be available. An ultimate consumption in the San Francisco Bay region of 400,000,000 gallons daily from this source is contemplated, and the aqueduct tunnel above the power house is designed for this quantity, so that the full amount of water may be diverted and used in the power house at once, thereby safeguarding the City's water rights and giving the City a marketable asset at an early stage of development. Below the power house, the tunnels from Moccasin Creek to the east foothills of the San Joaquin Valley are at present designed for 200,000,000 gallons daily, as the full quantity will not be required by the City for many years and as the saving in first cost and interest will greatly exceed the cost of driving a second parallel tunnel when it becomes necessary to do so at a later date. The tunnels in the Coast Range have been designed of the size specified for the same reason. The San Joaquin Valley pipe and the pipe from Irvington to San Francisco is made of only 60,000,000 gallons daily capacity, also to save initial cost and interest on premature investments.

The present scheme differs from the Grunsky and Manson plans principally in that the whole project is considered on very much broader lines, considering the future needs of a great metropolis and in accordance with the most modern developments of water supply engineering, and with all possible consideration for the ultimate development, not only of San Francisco, but also of the surrounding region whose growth and welfare are inseparably bound up with that of San Francisco. The advances in this branch of engineering in the last ten years have been very marked, and the City is getting the benefit of the experience of other large water supply projects developed in the past 15 years by our larger American cities.

The principal physical difference is that the grade-line conduits following the canyon walls of the Sierra Nevada, and much of the steel pipe in the San Joaquin Valley foothills and the Coast Range, as planned by Mr. Grunsky and Mr. Manson, are replaced in the present plan by permanent tunnels which also shorten the total mileage. A great part of the power generated under the older plans would have been consumed in pumping the water over the Coast Range, while the present plan develops the greatest economy by taking the water from its source to the receiving reservoir in San Francisco

entirely by gravity, leaving all of the power developed in transit available for other uses and entirely eliminating the operating costs of pumping. While these tunnels are more expensive to construct in the first place, the greater outlay is justified by the increased reliability of service, decreased maintenance charges, and increased power product.

The Freeman plan of 1912 called for all tunnels to be built at once for 400,000,000 gallons daily capacity; the San Joaquin Valley pipe line for 240,000,000 gallons daily, and the pipe line from Irvington to San Francisco for 50,000,000 to 100,000,000 gallons daily. In the interests of economy and due to the restrictions in utilization of irrigation waters in the Raker Bill, the size of initial installation has been modified as already described.

Summary of Work Already Accomplished

The preliminary work already done has been described in detail in the various annual reports of the City Engineer and in Exhibit "F" of this report. The extent of these activities has been limited only by the small amount of funds heretofore available. Lands and rights of way for reservoirs, aqueducts, power development and railroad purposes have been secured by application to the government authorities or by purchase from private parties; stream gagings have been kept up and new stations established; water rights have been maintained; railroad and aqueduct surveys have been made; roads and trails have been built; the clearing of the Hetch Hetchy reservoir site and the construction of the tunnel to divert the river past the dam site are in progress; and work has commenced on the railroad to haul materials and supplies to the various centers of activity from the Sierra foothills to Hetch Hetchy.

Program of Development

Before active work on permanent construction can be started, it remains to finish the reservoir clearing; complete and equip the railroad; complete the diversion tunnel and build a diversion dam; build additional roads and construction camps; construct a complete hydro-electric power system for construction purposes; and complete the designs for the permanent structures.

In proportion to the relative costs of the two projects, much more preliminary work has been required on the Hetch Hetchy than on the Catskill development because of the fact that the entire Catskill line lies in a settled region of low elevation, accessible everywhere by means of previously existing railroads and wagon roads, while the City's reservoir sites and much of the aqueduct line are in rough mountain regions inaccessible except by rough trails, almost uninhabited, remote from the railroad, and with few wagon roads.

It is estimated that, including the preliminary work yet to be accomplished, eight years will be required for the complete construction of the Hetch Hetchy system.

It is considered very important that the Moccasin Creek power plant be put in operation as early as possible in order to put the City's water to actual use. The work on the dam and the aqueduct above Moccasin Creek will

therefore be started as soon as the railroad is available to haul construction materials and supplies, and rushed to completion. In the meantime, exploratory work and studies for the location and design of the Sierra tunnel west of Moccasin Creek, the San Joaquin Valley pipe line, the Coast Range tunnel and the pipe line from Irvington to San Francisco will be carried on, and the necessary rights of way for these sections of the aqueduct will be acquired as soon as they have been definitely located. Actual construction on the Coast Range tunnel, which, as regards time of completion, is the controlling feature of the group just enumerated, will begin as soon as proper location studies are made, rights of way obtained and sufficient funds made available to carry it on in addition to the work in the Sierras. The dominant feature of our development plan so far has been to underwrite and absolutely secure our mountain rights against all kinds of predatory trespassers who have been endeavoring to encroach on and obstruct the City's developments in the high Sierras.

The time at which the City will be able to begin the generation of power at Moccasin Creek is governed by the time necessary to complete the longest single section of the nineteen-mile tunnel aqueduct above the power house, namely, the section extending from the point of diversion on the main Tuolumne River (Early Intake) to the South Fork crossing, a distance of 23,700 feet (4½ miles), where all work will be done from the two portals, as the tunnel grade is so far below the ground surface as to prohibit the sinking of shafts to secure additional working faces.

The Elizabeth Lake tunnel of the Los Angeles Aqueduct, as previously noted, is 25,000 feet in length and was worked from four headings. Nearly six years' time was required for its construction. However, unstable and water-bearing rock caused much trouble there. It is thought that five years will suffice for the Early Intake-South Fork tunnel. Although only two headings can be used, the rock is hard, the formation apparently uniform, and little trouble from water is to be expected.

The dam will probably be completed a year earlier than the tunnel, if both are started at once, but this margin is not large enough to warrant delaying the dam and besides there is the further desirability of having stored waters accumulated for a year in the Hetch Hetchy reservoir.

The construction of the Moccasin Creek power plant should be started two years before the estimated time of completion of the tunnel.

The Coast Range tunnel will be much more difficult to construct than that in the Sierra. Very careful geological investigation will be necessary before definitely locating the line, as large quantities of water and much unstable ground will be encountered. The greatest distance between shafts will be about three miles. A six-year construction period is allowed.

Exhibit "G" shows in tabular form the work already done from the inception of the Hetch Hetchy project, and the program for future work, so far as it is possible to lay out a definite plan at this time, and assuming that the work will not be hampered by financial or other limitations. This schedule shows the Moccasin Creek power plant ready for service at the end of 1921

and the entire system ready to deliver water to San Francisco at the end of 1923.

No consideration is given here to the City distributing system, as it is expected that by 1923 the properties of the Spring Valley Water Company will have been acquired.

Organization of Engineering Force

The remarks on this subject already quoted from the report of the consulting engineers on the Los Angeles Aqueduct (pages 3, 4 and 5) apply with equal force here.

A tentative organization diagram for the Hetch Hetchy Water Supply engineering force is attached as Exhibit "H."

HETCH HETCHY DEVELOPMENT PROGRAM FOR 1916

During the present year the chief works contemplated are the construction of the Hetch Hetchy Railroad, for which the contract has already been awarded; the completion of the diversion tunnel and diversion dam; preparation of the foundations for the main Hetch Hetchy Dam; preparation for the construction of a temporary power plant to supply electric current for the construction operations at the dam site; exploration borings by diamond drilling to determine the character of the formation through which the aqueduct tunnels will pass; the completion of the contract for clearing the reservoir; the continuation of the aqueduct tunnel from Early Intake toward South Fork; additional road and trail construction around Hetch Hetchy reservoir and the continuation of hydrographic, meteorological and survey work as well as the protection of the City's water rights in and adjacent to the Valley, including surveys, location and purchase of aqueduct right of way across San Joaquin Valley.

It is deemed inadvisable to undertake any of the other heavy construction on this project until the completion of the railroad line. In his report of February 17, 1915, the City Engineer submitted the figures of cost for transportation by rail as compared with auto truck haul. The cost of transporting 225,000 tons of material by motor truck was therein estimated at $3,095,000, and the cost of hauling the same amount by railway, $2,010,000, leaving a balance in favor of railroad haul amounting to $1,085,000. In view of these figures, it is planned to defer whatever construction requires considerable haul of material until the railroad has been completed. Not only is the rail haul of cement more economic on a per ton basis, but also it is a most difficult undertaking to control the economic handling by truck of cement in sacks, some of which will be damaged in transit and leave room for endless controversies.

Lower Cherry Power Development for Construction Purposes

A large amount of power will be required for operating the machinery of the various construction plants at the dam site and along the tunnel aqueduct line.

Electric power is greatly to be preferred, and it is proposed to develop this power by diverting water from Cherry River, leading it through a canal to a point near Early Intake, and dropping it through a temporary power plant. A high tension transmission line, 12 miles in length, will connect this plant with the dam site and another line, 20 miles in length, will follow along the aqueduct line as far as Moccasin Creek, with a sub-station at each portal, shaft and adit of the tunnel aqueduct.

The canal will have a capacity of 200 cubic feet per second, and will be a permanent structure, as it is intended that after the construction period is over it shall remain in service for the purpose of making the water of Cherry Creek tributary to the tunnel aqueduct. This early applied use of the City's water rights on Eleanor and Cherry Creeks will obviate any possibility of successful future interference by enterprising speculators seeking to gain a foothold in that region. The development of power at this point will therefore serve a double purpose in sealing the gates against future intruders, but the value of the power output for construction use alone will justify the expense.

It is essential, of course, that the power plant should be ready to furnish power at the commencement of operations on the dam and tunnel. It will therefore be necessary to begin work on the hydraulic development as early as possible.

The work which should be completed on the temporary power plant during the present calendar year is as follows:

1. *Storage Dam* at Lake Eleanor: To carry the plant through the low water season, it is necessary to store water at Lake Eleanor. A suitable site for a low and inexpensive dam exists.

2. *Diversion Dam* on Cherry River: To divert the water of Cherry River (which includes the combined flow of Cherry and Eleanor Creeks) into the canal.

3. *Canal:* Conveying water from the point of diversion to the power drop at Early Intake.

4. *Power House:* Excavation of site.

The building and equipment of the power plant, and the penstock pipe supplying it, can be accomplished in a short time, and as it involves the transportation of considerable material and equipment, it will be deferred until the Spring of 1917, when the City's railroad will be in operation.

It is highly important, however, that the dams and the canal shall be constructed during the present calendar year. If delayed, power cannot be furnished as early as it will be needed. Also, by having these structures completed before the end of this year, we gain the additional advantage that before being put in service they will have had the benefit of several months in which to settle and season. The weak spots which are always found in a ditch in soft ground will have developed and been repaired, thus insuring the plant against interruption of service due to breaks along the canal line.

The cost of the construction work to be undertaken and completed during the calendar year 1916, as described above, together with the roads and trails necessary to make all portions of the work readily accessible, is estimated at

$120,000. As this work is in large measure necessitated for the maintenance of our water rights in Cherry and Eleanor Creeks, this amount is divided in Exhibit "J", $20,000 of it being charged directly to "Water Rights and Protective Work".

Construction at Hetch Hetchy Dam Site

As soon as the flow waters of the river subside to sufficient extent to allow of the construction of the diversion dam across the channel, this work will be undertaken. It is estimated that this structure will be completed by September 15, 1916, and the river diverted past the site of the main dam, the preparation of the foundations for which will then be immediately begun.

It is estimated that the total stripping on the main dam site will be approximately 32,000 cubic yards, of which about 20,000 cubic yards will be on the lower part of the foundations (below elevation 3510). Roughly, 13,000 cubic yards of the above mentioned 20,000 cubic yards will be solid rock excavation (to elevation 3560 ±):

It will be more economical to strip the upper parts of the dam site as the main dam is constructed, and for the present season only the lower part will probably be attacked. The approximate cost will be as follows:

For installation of additional derrick	$ 2,750
13,000 cubic yards of sand and boulders @ 45c	5,850
7,000 cubic yards of rock (removed by hand picking—no heavy shooting allowed) @ $2.70 per cubic yard	18,900
It will probably be necessary to investigate the foundations by drilling or drifting, or both, but this cannot be determined until the bedrock is cleaned off. An allowance is made here for 2,000 lineal feet of hole grouted at $1.50	3,000
Cut-off wall at lower end of dam site	8,500
Total for low foundation work	$39,000

In addition to the above, it will probably be desirable to clear the channel below the dam site this year. This cost will be about $13,000.

Miscellaneous Work

Proceeding along the aqueduct westerly from the Early Intake, it is proposed to bore eighteen diamond drill holes approximately a mile apart varying in depth from 40′ to 928′. Six of these holes averaging 650′ in depth will be west of the westerly boundary of the Stanislaus National Forest and the remainder will be between this boundary and the Early Intake.

For the information of this Department, it is essential that accurate records covering a long period of years be kept of the hydrography of the Tuolumne and its tributaries. These will be continued by hydrographers assigned by the U. S. Geological Survey, working under the direction of the City Engineer.

Besides continuing the aqueduct tunnel westerly from Early Intake in order to protect the City's rights thereto, in accordance with provisions of San Francisco's Hetch Hetchy Grant, a new road will be constructed to the westerly portal of this tunnel on the South Fork of Tuolumne River.

Accident Insurance

So far, the City has been exceedingly fortunate in eliminating accidents by exercising the utmost precaution in all of its Hetch Hetchy construction. It is impossible, however, to predict that any work of this magnitude can be carried to completion without accidents, despite the utmost vigilance on the part of the engineers and inspectors. One fatality would consume more funds in indemnity than has been paid to the State Compensation Fund for insurance during the past six months. The advisability of continuing this insurance is therefore urged upon your Honorable Board. During the construction of the diversion tunnel the rate was higher than on any work which the City will perform during the coming year, and a material reduction in premium will therefore be made on all construction work undertaken since the enactment of the Workmen's Compensation Law. Contractors as well as municipalities figure in the cost of their construction work the additional expense of insuring their workmen.

Acquisition of Lands and Rights of Way

Provision should be made at this time for the acquisition of necessary rights of way through privately owned lands for the aqueduct tunnel, pipe lines and appurtenant structures all along the line from the high Sierra to the San Francisco Bay region. Such purchases can be made at lower prices at the outset of the project—as soon as the definite location has been decided on—than after work has been commenced on adjacent divisions. In particular, there is to be acquired a tract of 80 acres owned by Joseph Cavagnero on which to construct the Moccasin Creek power house and its appurtenant buildings and the re-regulating reservoir into which the water will be discharged after passing through the power house. This land will cost about $10,000. The $500,000 appropriation requested for these purposes includes provision for the acquisition of about 60 acres of lands in San Francisco for the Glen Park or San Miguel receiving reservoir.

Medical Service

In Exhibit "K", hereto attached, is recorded the gist of the agreement between the City of Los Angeles and the contractor to whom was deputized the work of providing hospital accommodations for employees of the Los Angeles aqueduct project. A similar arrangement by the City is suggested whereby the sum of 75c a month, or less, will be deducted from the wages of each City employee on this project, in consideration of which he will be provided with hospital attention and medicine in case of illness.

Hereto is also attached Exhibit "I", showing the condition of the Hetch Hetchy funds and appropriations to date; also Exhibit "J," wherein the amounts of money to be appropriated during the present year are set forth.

LIST OF EXHIBITS

A. General Map of the Hetch Hetchy Water Supply.
B. General Profile of the Hetch Hetchy Water Supply.
C. Map of the Hetch Hetchy Railroad and Tunnel Aqueduct in the Sierra Nevada.
D. Diagram Showing Average Daily Consumption of Water in San Francisco for each year from 1909 to 1915, inclusive.
E. Population and Water Consumption of San Francisco from 1900 to 1915, and estimated increase from 1916 to 1935.
F. Detail of Progress of Work in 1915.
G. Expenditures on the Hetch Hetchy Water Supply from 1900 to 1916, and estimated Annual Expenditures to the end of the construction period.
H. Tentative Organization of Engineering Force for the construction of the Hetch Hetchy Water Supply.
I. Condition of Hetch Hetchy Appropriations, February 4, 1916.
J. Appropriations Requested for Hetch Hetchy Water Supply Work to be executed from March to December, 1916.
K. Medical Service and Accidents to Employees on the Los Angeles Aqueduct.
L. Los Angeles Aqueduct: Organization of Engineering Force during construction period.
M. Catskill Water Supply of the City of New York: Annual Expenditures; Fluctuation of Contractors' Forces.
N. Catskill Water Supply of the City of New York; Engineering Bureau Organization.
O. Catskill Water Supply of the City of New York: Fluctuations in Engineering Bureau Forces.

HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF
SAN FRANCISCO, CALIFORNIA.

GENERAL MAP
HETCH HETCHY WATER SUPPLY
TO ACCOMPANY REPORT OF M.M.O'SHAUGHNESSY, CITY ENGR.
MARCH 1916.

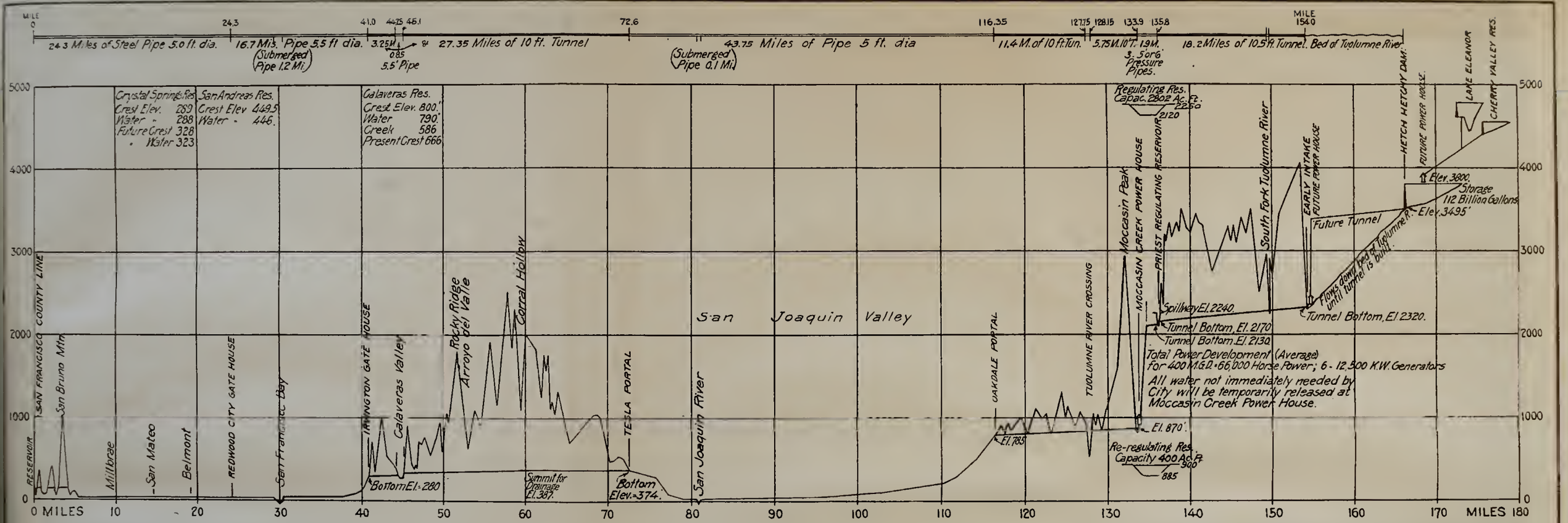
DEPARTMENT OF PUBLIC WORKS

APPROVED M.M. O'Shaughnessy CITY ENGINEER.

0 10 20 30 40 MILES

B97

EXHIBIT A



HETCH HETCHY WATER SUPPLY

OF THE CITY AND COUNTY OF

SAN FRANCISCO, CALIFORNIA.

GENERAL PROFILE

HETCH HETCHY WATER SUPPLY

TO ACCOMPANY REPORT OF M.M.O'SHAUGHNESSY, CITY ENGR.,

MARCH 1916.

DEPARTMENT OF PUBLIC WORKS

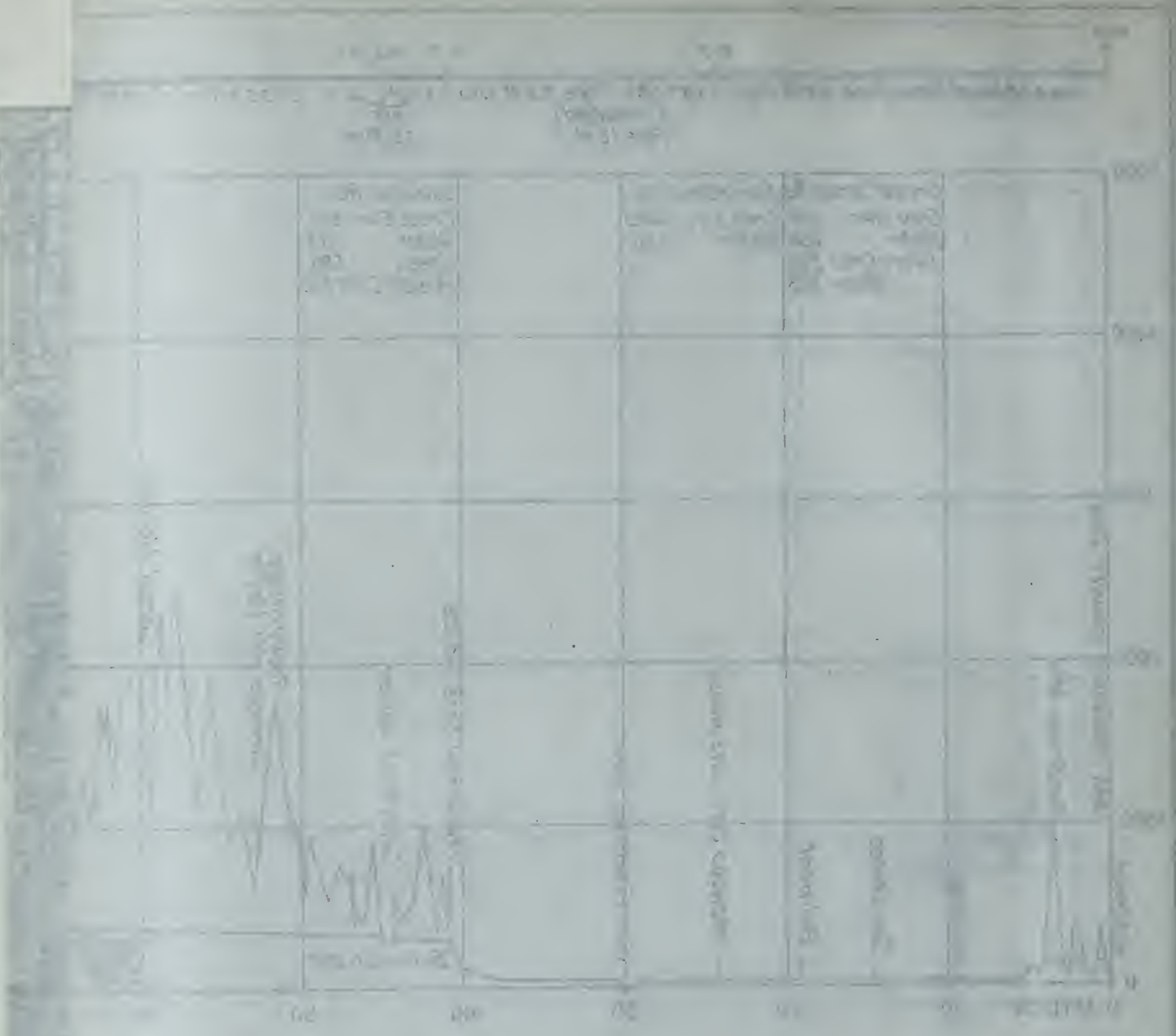
APPROVED ..... M. M. O'Shaughnessy ..... CITY ENGINEER.

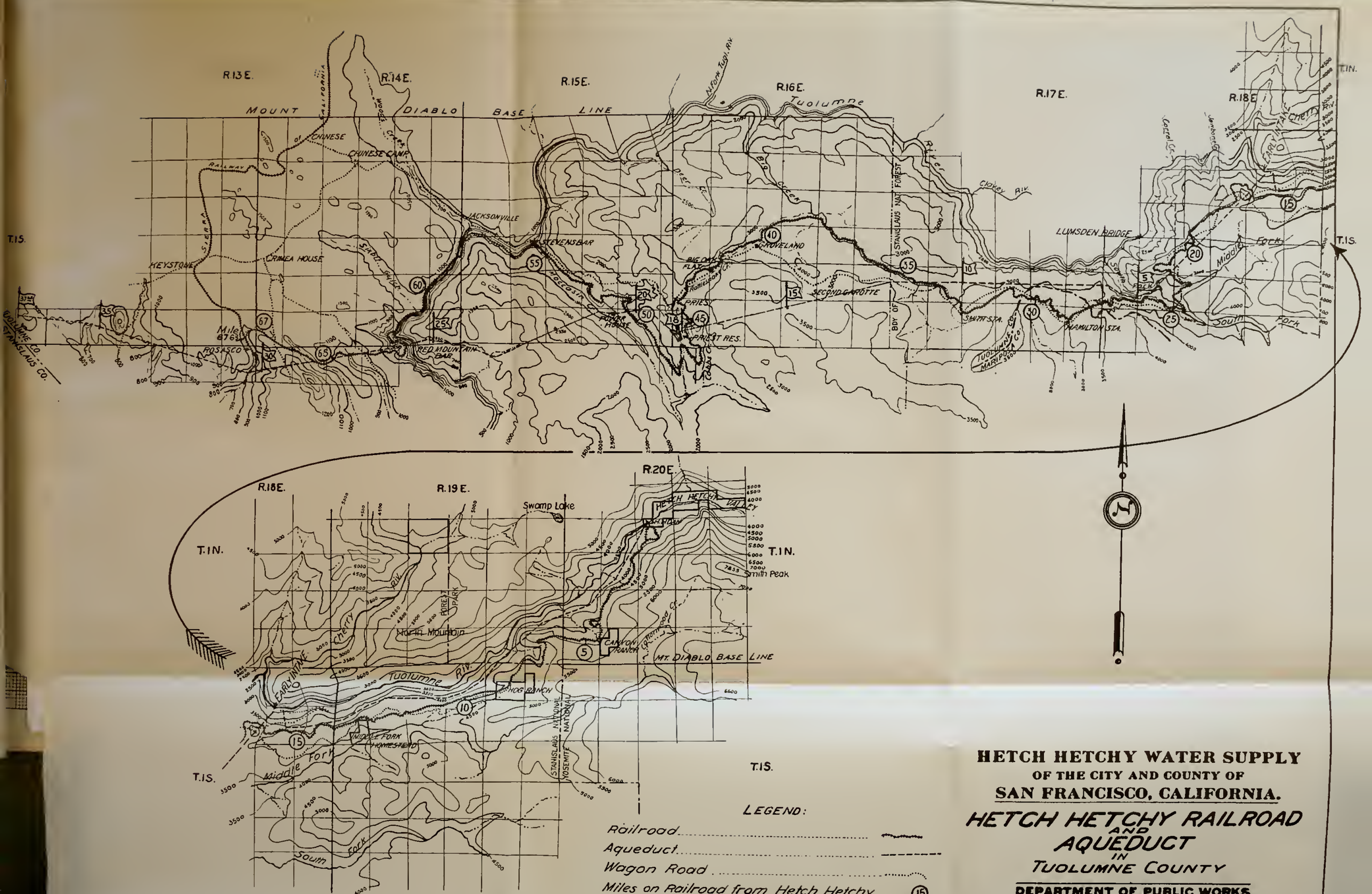
BY. L.B.K. TRACED . L.B.K. CHECKED . L.B.K.

SCALE. Hor: 1" = 10. Miles .... DATE. Mar. 1916 ...
Vert. 1" = 1000 Feet

B 96

EXHIBIT B





LEGEND:

Railroad .....

Aqueduct .....

Wagon Road .....

Miles on Railroad from Hetch Hetchy ..... (15)

Miles on Aqueduct from Early Intake 10

HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF
SAN FRANCISCO, CALIFORNIA.

HETCH HETCHY RAILROAD AND AQUEDUCT IN TUOLUMNE COUNTY

DEPARTMENT OF PUBLIC WORKS

APPROVED ..... CITY ENGINEER.

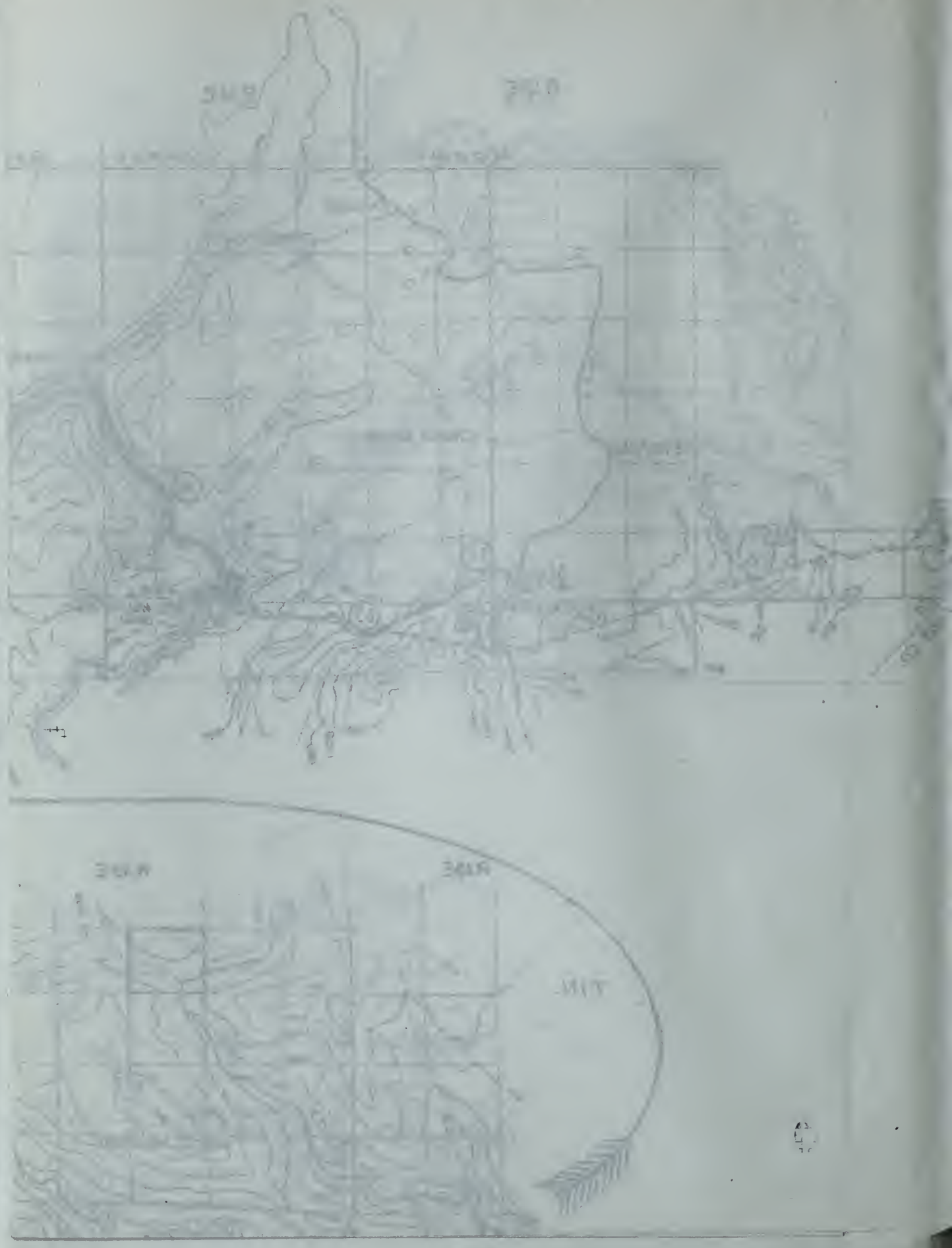
BY. EB ... TRACED EB .... CHECKED. ...

SCALE. 1/2 in = 1 mi. .... DATE. Mar. 1916. ....

MILES 1 0 1 2 3 4 5 MILES

B 98

EXHIBIT C.



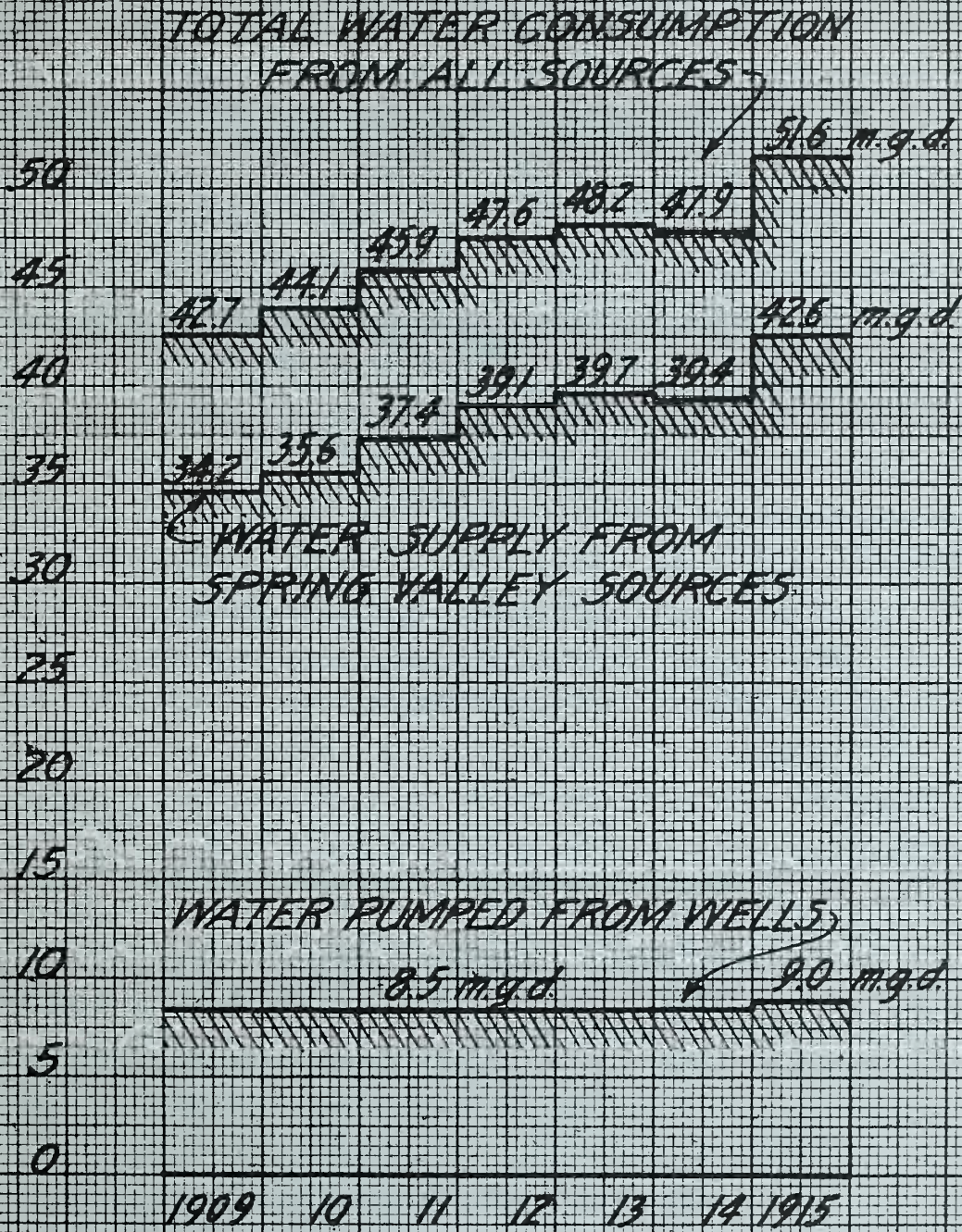
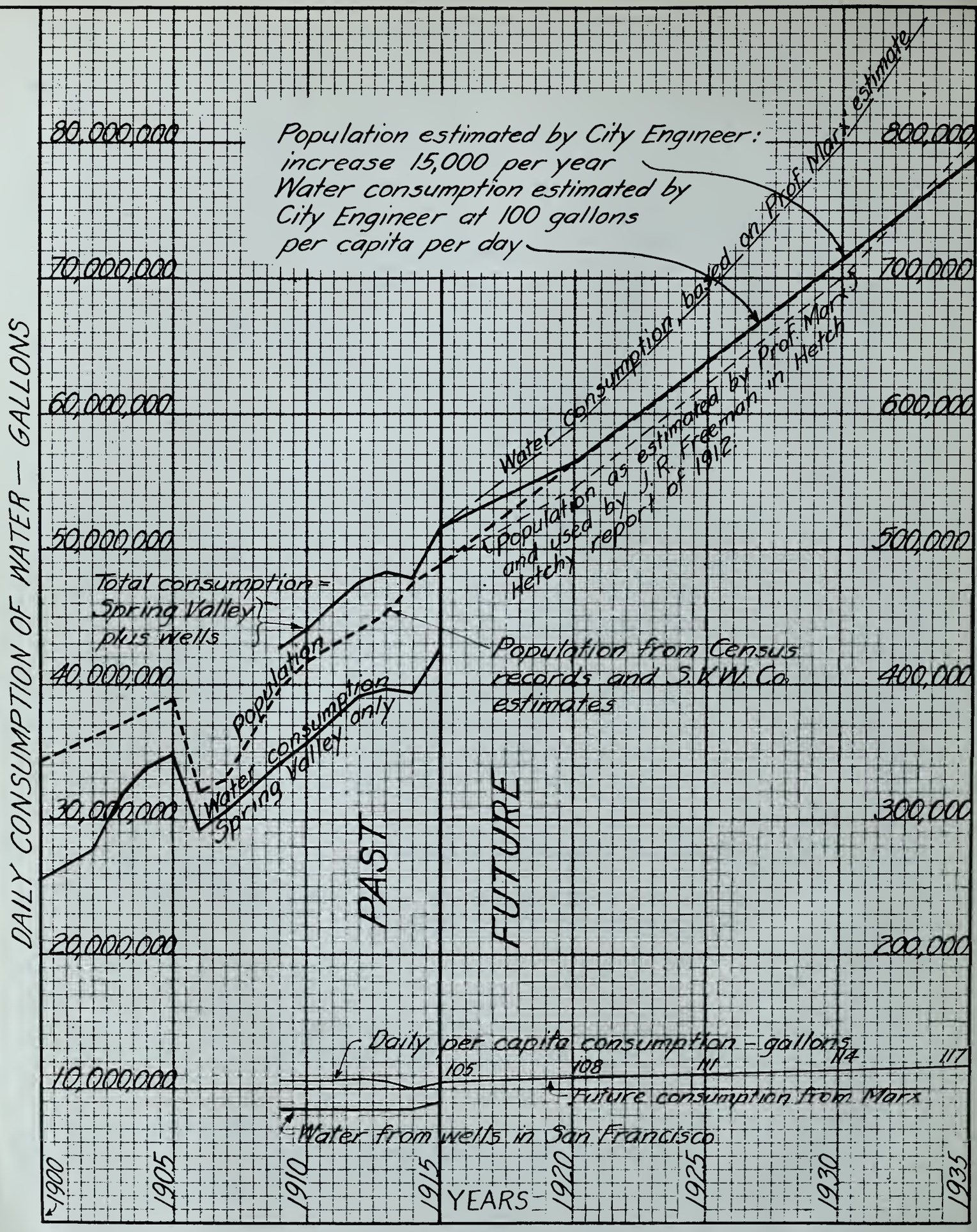


DIAGRAM SHOWING
AVERAGE DAILY CONSUMPTION OF WATER
IN SAN FRANCISCO
FOR EACH YEAR FROM 1909 TO 1915 INCLUSIVE

TO ACCOMPANY REPORT OF
M.M. O'SHAUGHNESSY, CITY ENGINEER,
MARCH, 1916.

EXHIBIT D.



POPULATION AND WATER CONSUMPTION OF SAN FRANCISCO FROM 1900 TO 1915, AND ESTIMATED INCREASE TO 1935.

TO ACCOMPANY REPORT OF M. M. O'SHAUGHNESSY, CITY ENGINEER, MARCH, 1916.

EXHIBIT E.

EXHIBIT "F"

DETAIL OF WORK UNDER CONSTRUCTION

Since filing my last annual report of February, 1915, work has been done on the development of the Hetch Hetchy Water Supply and power system as follows:

WATER RIGHTS AND PROTECTIVE WORK

According to the provisions of San Francisco's Hetch Hetchy grant the development of the City's Sierra water supply "shall be prosecuted diligently and no cessation of such construction shall continue for a period of three consecutive years, and in the event that the Secretary of the Interior shall find and determine that there has not been diligent prosecution of the work or of some integral and essential part thereof, or that there has been a cessation of such construction for a period of three consecutive years, then he may declare forfeited all rights of the grantee herein as to that part of the works not constructed, and request the Attorney General, on behalf of the United States, to commence suit in the United States District Court for the Northern District of California for the purpose of procuring a judgment declaring all such rights to that part of the works not constructed to be forfeited to the United States".

Pursuant to a policy of active development, construction was started simultaneously at several locations in 1915, the extent of activity at each point being determined by the funds available from a restricted sale of 4½% bonds due to market conditions, and by the relative value of each unit in furthering the City's plans.

At the Early Intake, twelve miles below Hetch Hetchy dam site, water released from that reservoir site, and flowing along the natural bed of the river channel, will be diverted into pressure tunnel 10½ feet in diameter, which for some years to come will be the easterly terminal of the City's main aqueduct. This tunnel will pass beneath the mountain backbone on the south side of the Tuolumne River for a distance of 19 miles, to the Priest's Hill regulating reservoir near Moccasin Creek. The vicinity of the upstream intake portal has been excavated and the tunnel face started ready for power drills. The excavation of a bench in the slope above the river floods for the aqueduct leading from the Early Intake diversion dam site to the tunnel portal is also under construction, and in this portion of the aqueduct will be placed necessary sand screens and scouring chambers to automatically intercept any floating sand or debris, thereby preventing clogging of the aqueduct and dependent reservoirs.

A suspension foot bridge was built across the river at Early Intake to allow the men working on the tunnel to cross over to the construction camp, which will be built on the northerly bank of the river where advantage can be taken of whatever sunshine is available in this deep canyon for sanitary reasons.

Work on the Early Intake road, begun in 1914, was continuously prose-

cuted with a small force until the very heavy snowfall necessitated its discontinuance in December, 1915. This road is now approximately 80% completed. The work has just been resumed for this year.

The nine mile road from Hog Ranch to Hetch Hetchy dam site, constructed by the Utah Construction Company, under Contract No. 1, was surfaced in the spring of 1915, so as to put it in condition for the heavy wagon loads which were hauled for the installation of the sawmill, compressor, and other work.

Following the surveys of 1914, the application map for which was approved by the Secretary of the Interior on January 21, 1915, a road was constructed from Hetch Hetchy camp down into the floor of Hetch Hetchy Valley. This road has a length of .85 mile and was built on a 10% grade. It allows of access to Hetch Hetchy Valley by team or auto truck, which has been considered necessary as a construction adjunct to the main dam. The road was constructed entirely by day labor by City employees.

Trails were built from Hetch Hetchy camp down to and around the dam site and a road was built to allow of the hauling and installation of all plant, to be used in construction of not only the Diversion Tunnel, but also the Diversion and Main Dams.

A trail was begun from the main road between Colfax Gate and the Toll Bridge, leading toward the proposed aqueduct crossing on South Fork. This trail has not yet been completed.

In conjunction with the Forest Service and other interested parties, a bridge was built over the Middle Fork on the road between Hog Ranch and Sequoia. Before this bridge was built the road was impassable when the Middle Fork was at high stages, and it was then necessary to ford the river.

PERMANENT CAMP

Following the topographic survey of the Hetch Hetchy camp, studies and designs were made in the office for the main camp for housing the men to be engaged on the construction of the Hetch Hetchy Dam.

Late in June clearing of portions of the camp site was begun. Work was continuously prosecuted on the camp construction until the heavy fall of snow in December. The work was then practically discontinued, at the present time there being but a few men engaged thereon.

The construction of camp buildings at the Hetch Hetchy dam site was begun in September, 1915, the first building constructed being the dining room, 120 feet by 40 feet. This was followed by building of bunk houses and cement warehouse. There have been built also one 3-room cottage, a hospital, wood house, oil house, meat house, and other buildings. A water system with wooden tanks and 2-inch water mains has been completed, and roads around the camp have been undertaken.

DIVERSION TUNNEL

For the purpose of by-passing the stream flow of the Tuolumne River during the excavation of the foundations for the dam and the construction

of the dam proper, a tunnel was drifted at the dam site. This tunnel was commenced late in September. Owing to the difficulty of securing prompt delivery of the compressor plant, due to tardiness in plan approval by Interior Department officials, the work was begun by hand drilling. When the tunnel heading was well started, two crews were put on, working night and day, and the heading was drifted through on the 30th day of December.

The main tunnel is to be 20 feet in diameter. The completed heading is approximately the upper half of the whole tunnel. The excavation of the bench on the remaining half is now being carried on. The rock is a very hard grade of granite requiring no timbering and is a good indication of the nature of the excellent foundation of the main Hetch Hetchy Dam. A portion of the spoil has been saved for use in the concrete construction of the diversion dam.

DIVERSION DAM

Preparations were made to construct the diversion dam to divert the river flow into the diversion tunnel, above mentioned, thereby unwatering the main dam site. A bench was made for hoisting engine, the engine installed, and derrick parts and cable hauled in and put in place preparatory to storing sand from the river bed. Lumber for flume and form construction has been delivered on the ground from Canyon Ranch sawmill.

The delivery of the cement to be purchased under Contract No. 8, for the construction of this dam, was delayed by early rains and snows so that it was not possible to prosecute the dam construction this winter, as contemplated. As soon as the material is received on the ground, the work will be carried on and the river water diverted past the foundation of the main dam at the dam site.

The commencement of both the Diversion Tunnel and Diversion Dam was delayed from April till August—four months—due to lack of approval of plan program by the Assistant Secretary of the Interior. It is needless to state that delays of this nature prove a hardship and serious handicap to the City, where the fair weather season is so short, due to winter snows, etc.

TELEPHONE LINE

The City's telephone line from Groveland to Hog Ranch was extended as a single iron wire from Hog Ranch to Hetch Hetchy Camp. Some repairs and improvements in the old line were also made. The line is now in operation from Groveland to Hetch Hetchy dam site.

CANYON RANCH SAWMILL

A site for the sawmill at Canyon Ranch in the City's property owned in fee was selected in the spring and in April grading was begun thereon. This was followed by felling and hewing of timbers sufficient to construct the first part of the frame for the mill. The final timber work was made with timber sawed at the mill.

Sawmill machinery, purchased under Contract No. 2, was delivered at

Chinese and hauled to Canyon Ranch during June. The machinery was completely installed early in July and sawing was begun on July 21.

Great care was observed to preserve the natural forest appearance of Canyon Ranch, and not mar the scenic features of the National Park by the City's activities. One of the means used was to leave untouched a screen of trees immediately next to the railroad.

Sawing was continued until November, when, on account of the snow fall, the mill was shut down. About 1,200,000 feet B. M. were manufactured during the season, a portion of this being surfaced. A large portion of this lumber was hauled to Hetch Hetchy dam site for use in permanent camps, a portion was used at the sawmill in construction of frame for the mill, office, bunk houses, etc., and the remainder was piled for seasoning. The area on which the timber was cut at Canyon Ranch has been cleared, the slash and brush burnt in a satisfactory manner. During December the mill was housed in, engines, etc., covered, and everything put in good style to withstand the winter storms.

There is now remaining on Canyon Ranch about 800,000 feet B. M. of timber, which can be cut by the mill. In the floor of Hetch Hetchy Valley there are about 2,000,000 feet B. M. of logs suitable for saw timber.

DEFENSE AGAINST OPPOSITION WATER AND POWER CONCERNS

The Yosemite Power Company has pending before the Department of the Interior applications for rights on the Tuolumne River in the National Park and Forest Reserve, which conflict seriously with the development works as proposed by the City. A determined stand was made by this office against the United States Government approving the validity of these claims, hydrographic and other data was prepared and submitted to United States Government officials and studies made of the company's proposed hydro-electric power development. The City Engineer with the City Attorney and the Clerk of the Board of Supervisors left for Washington, D. C., on January 18, 1916, to oppose the claims of this company, which is controlled by the Hammond interests. The hearing of both sides was held before the Secretary of the Interior on January 26th, 27th, and 28th, and the objections presented by City officials taken under advisement by him. Little doubt is felt of a verdict favorable to the City, for in a similar proceeding in 1912, Ex-Secretary of Agriculture Wilson ejected the National Park Electric Company, another wildcat concern, from the National Forest at the request of the City under conditions which were practically identical with those obtaining in the present case.

CONTRACTS

The following contracts were operative during the past year:

Contract No. 1: "For Constructing Road from Hog Ranch to Hetch Hetchy Dam." This work was begun in August, 1914, and completed in February, 1915, by the Utah Construction Company, at a total contract price

of approximately $180,000. 9.09 miles of 22-foot road-bed was graded. The maximum grade is 4% and the minimum radius of curvature 191 feet. The greater part of the material handled in grading was solid granite. The road-bed was later surfaced, as elsewhere noted in this report, and is now being utilized for the transportation of machinery, materials and men to and from Hetch Hetchy Valley. It will form a part of the road-bed for the railroad now being constructed under Contract No. 7. Previous to the construction of this road, the Hetch Hetchy Valley was accessible only by trail.

Contract No. 2: "For Furnishing Sawmill Machinery." Bids were received on April 14, 1915, and the contract was awarded on April 19, to the Eby Machinery Company, for the sum of $4,975. Final payment was recommended on August 31, after a successful trial run of the machinery.

Contract No. 3: "For Furnishing Logging Engine." Bids were received on April 14, 1915, and the contract was awarded on April 28, to the Western Equipment Company, for $2,950. Final payment was recommended on August 19, after a successful trial run of the logging engine.

Contract No. 4: "For Clearing Portion of Hetch Hetchy Reservoir Site." Bids were received on September 15, 1915, but were rejected (September 20) on account of irregularity in the lowest bid. The contract was re-advertised, bids being received on September 29th, and award was made to A. J. Reeder on October 1st, for the estimated sum of $31,675, with a possible bonus of $1,500. This work is still being prosecuted, with a force of nearly 150 men, and will probably be finished in the early spring. A large amount of cord wood and of saw logs will be turned over to the City as a result of the work done under this contract. It may prove advisable to move the sawmill from its present site to Hetch Hetchy Valley, when the sawing of the timber now standing on Canyon Ranch is completed.

Contract No. 5: "For Furnishing Air Compressing Plant and Drills." Proposals were received on September 8, 1915, and the contract awarded on September 15th, as follows:

> Proposition No. 1—Boilers, to the Chicago Pneumatic Tool Company, for $2,877.
>
> Proposition No. 2—Air Compressor, to Ingersoll-Rand Company of California, for $3,019.
>
> Propositions Nos. 3, 4 and 5—For Drills, Receivers, Sharpener and Accessories, to Rix Compressed Air Drill Company, for $4,431.50.

This machinery was delivered to Hetch Hetchy dam site in November. It has all been assembled and is almost ready for regular operation. Partial payments have been made.

Contract No. 6: "For Furnishing Hoisting Engine and Boiler." Proposals were received on October 8, 1915, and contract awarded on October 11th to A. L. Young Machinery Company for $1,357. The engine was delivered at Hetch Hetchy dam site in November and installed, as noted under "Diversion Dam."

Contract No. 7: "For the Construction of the Hetch Hetchy Railroad." Specifications were prepared for this work and proposals received on October 28, 1915. The proposals were six in number, the lowest being that of F. Rolandi of this City for the estimated sum of $1,543,080.74. This bid was accepted by the Board of Public Works on December 6, 1915. Owing to the difficulty of selling bonds to finance the contract, construction had not yet begun at the end of the year, although preliminary work was being carried on. Since January 1, 1916, however, bonds to the amount of $1,250,000 have been sold to Blyth, Witter & Co., which assures the completion of this contract, and work has now been started.

This contract will include grading 58 miles of line, from Hog Ranch to Rosasco, furnishing all materials, and constructing a railroad over the total 67.63 miles, with necessary sidings and other accessories, from Rosasco to Hetch Hetchy dam site.

This Department gratefully acknowledges the co-operation of City Attorney Long for the effective work done in rapidly securing the railroad right of way, and other activities bearing on the legal phases of the project.

Contract No. 8: "For Furnishing Cement." Bids were received October 23rd, 1915, and contract awarded on October 26th to the Santa Cruz Portland Cement Company, for furnishing at Chinese Station 3,975 barrels of cement. The contract price was $10,613.25. Delivery was begun immediately upon award of contract, but the early rainfall and snow interfered with the hauling to such an extent that the completion of delivery had to be deferred until the end of winter. At the present time there have been delivered at Chinese Station 2,350 barrels. This cement is to be used in the construction of the Diversion Dam, the preliminary work for which has already been done.

Contract No. 9: "For hauling cement from Chinese, a station on the Sierra Railway of California, Tuolumne County, to Hetch Hetchy Dam Site." Bids were received on November 5, 1915, and contract awarded on November 6th to Charles B. Dunham at $23 per ton. Hauling was begun immediately upon award of contract and carried on intermittently, as rapidly as the weather and conditions of roads would permit. Hauling has now been discontinued, with some cement delivered at Hetch Hetchy Dam Site and some stored en route.

Stream Measurements

Hydrographic and meteorologic observations have been continued at Hetch Hetchy, Eleanor Creek and Cherry Creek. This work has been conducted by men assigned by the Water Resources branch of the United States Geological Survey, under the direction of the City Engineer.

The stream measurements on the Tuolumne River, near Hetch Hetchy dam site, were conducted at the new gaging station, three-quarters of a mile below the dam, the construction of which was almost completed during the year 1914. During 1915 a stone house with reinforced concrete roof was built at this station and the measuring sections for cable work were put in good condition. The work was completed in September and the old gaging

station abandoned, as it was impracticable to continue the record there on account of construction work.

During October and November, 1915, a new station was constructed on Falls Creek, about one-quarter mile above Wapama Falls. Falls Creek is tributary to the Tuolumne River at a point in Hetch Hetchy Valley about one mile above the dam site.

At the Falls Creek gaging station the well is of stone and the house of reinforced concrete. A cable was installed a short distance above the gage. The station is equipped with a Stevens recording gage, the first one of this type to be installed by the City.

The old channel leading from Falls Creek below the gaging station, and diverting water to Tueeulala Falls, which for many years has been almost entirely blocked by logs, some buried deep, was cleared of obstructions.

At Cherry Creek gaging station the old wooden well was replaced by a reinforced concrete well and house. Reinforced concrete anchorage was placed for the cable at the measuring section and a ferry constructed.

At Eleanor Creek a new station was built at a point below the dam site. The well was built of stone to a height of 7 feet and of reinforced concrete above that point. Considerable blasting was required in the construction of this station. The work was completed on November 9th, and a new hydrographic record started on November 13th, at which time the old Eleanor Creek record was discontinued.

SURVEYS

Hetch Hetchy Railroad: The location survey of the Hetch Hetchy Railroad was completetd in June, 1915. The line as now located has a total length of 67.63 miles, from the camp at Hetch Hetchy dam site to the connection with the Sierra Railway of California, at a point about one-half mile northerly from Rosasco Siding. The maximum grade is 4% and the maximum curvature 30° or a radius of 191 feet. The grade going east has in all instances been compensated for curvature at the rate of .04% per degree of curve, and going west this condition has been observed from Colfax Gate to Rosasco, with the idea that future developments may warrant the maintenance of a permanent railway from Rosasco, via Groveland, to Colfax Gate, and thence up the canyon of the South Fork to Crocker's or Sequoia. In such event the alignment and grade, as now located, would prove quite feasible for regular railway operation.

The railroad is to have a uniform width of roadbed of 16 feet at subgrade on both cuts and fills, except for that portion from Hog Ranch, through Yosemite National Park, to Hetch Hetchy dam site, which is 22 feet wide.

Aqueduct Surveys: Upon the completion of the location survey of the Hetch Hetchy Railroad, the survey party was transferred to Early Intake and proceeded to locate the Hetch Hetchy Tunnel Aqueduct from that point to the westerly boundary of the Stanislaus National Forest. The relocation of this line was determined after extensive cost analyses, as well as geological studies.

The new aqueduct line crosses the South Fork of Tuolumne River at a point near the confluence of the Middle Fork, the crossing being a very low bridge. With the old aqueduct location, an expensive inverted siphon would be necessary, in which the water would be under very high pressure. This undesirable feature is eliminated in the revised location, which places this 19-mile section of the aqueduct on a uniform gradient.

The location survey for the new aqueduct line has been completed to the westerly boundary of the Forest, and application maps and field notes to be presented to the Department of the Interior are about to be prepared. Some of this relocation survey was run through the precipitous gorge of the South Fork of Tuolumne River where the surveyors had to be suspended by ropes. The nature of the work required great accuracy and the survey was made with extreme care. Concrete monuments were set on the permanent points of the survey.

A preliminary line has been run from Priest Reservoir to the Moccasin Creek power house site, and thence a location survey has been run to Red Mountain Bar. At this point the aqueduct will cross the Tuolumne River on a structure, the nature of which has not yet been definitely determined. For purposes of study, a detail topographic survey was made of the site of the proposed crossing. The survey has been continued from here to the westerly boundary of Tuolumne County, which will be approximately the end of Tunnel Aqueduct and the head of San Joaquin Valley pipe line.

Miscellaneous Surveys: In December, 1914, the City Attorney requested that this office make a survey of the exterior boundaries of an 80-acre tract owned by the Yosemite Power Company in Poopenaut Valley, some two miles below Hetch Hetchy dam site. This survey was made in January, in the face of great difficulty, owing to the heavy snow fall. A map of the exterior boundaries, with some topography, was made and delivered to the City Attorney's office.

Preliminary to the clearing of the floor of Hetch Hetchy Valley, to the elevation which was to be flooded by the construction of the Diversion Dam, an average depth of about 30 feet, a survey was made of the 3,560-foot contour, which was flagged out on the ground for the guidance of the men engaged in clearing the reservoir site.

The Hetch Hetchy dam site was accurately resurveyed and topographic map made thereof. This map was the basis of final studies of type of dam to be constructed, and also of location of this and various appurtenant structures.

In the operation of the sawmill at Canyon Ranch, governmental regulations of the Yosemite National Park necessitated confinement of our timbering operations strictly to the lands owned by the City at Canyon Ranch. To insure this object, a survey was made of the exterior boundaries of this land. The corners and lines were marked and the sawmill force instructed to keep within them. This work was done in July.

For the purpose of making descriptions of the rights of way along the Hetch Hetchy Railroad, resurveys were made of the townsites of Big Oak Flat and Groveland. The original surveys of these townsites were very

roughly done in the mining days of 60 years ago, and without the resurveys it was impossible to determine with any accuracy the location of the property lines. This work has now been completed and the rights of way are being definitely established as a result of it.

The Indian lands in the Big Creek Valley, near Groveland, were surveyed, as well as a number of mining claims along Moccasin Creek, as the railroad traverses these lands and the descriptions were needed for right of way purposes.

The last survey work done during the year was the beginning of cross-sectioning of the railroad line. For this purpose the survey party was divided, one party working from Rosasco toward Jacksonville, and the other from Jacksonville toward Priest. This cross-section work will determine definitely the yardage of grading done by the contractor under Contract No. 7, for constructing the Hetch Hetchy Railroad.

ALAMEDA CREEK HYDROGRAPHY

The work of gaging the water sources of the Spring Valley Water Company, in Alameda County, begun in 1914, has been continued during the year. The accumulation of accurate data and determination of the reliable yield of these sources is of great importance to the City in connection with not only any future purchase of the Spring Valley Water Company, but of any controversy in which the Company and the City may be involved.

APPLICATIONS TO DEPARTMENT OF INTERIOR

Application map of the Hetch Hetchy Tunnel Aqueduct, from the west boundary of the Forest to Priest Reservoir, was prepared and filed, together with field notes, in the Sacramento Land Office on March 9, 1915, and approved by the Secretary of the Interior on June 1st.

Amended application for Lake Eleanor Reservoir and application for Cherry-Hetch Hetchy Tunnel Aqueduct in Stanislaus National Forest were filed March 9th, and approved, respectively, December 27th and December 24th.

Applications for the following rights of way were also made:

Hetch Hetchy Railroad, from Hog Ranch to west boundary of Forest, filed May 28, approved October 12.

Hetch Hetchy Railroad, from west boundary of Forest to Priest Reservoir, filed June 11, approved October 15.

Hetch Hetchy Railroad, from Priest Reservoir to Red Mountain Bar, filed August 18, approved October 12.

Hetch Hetchy Railroad, from Red Mountain Bar to Rosasco, filed November 1, approval still pending.

During the year the City received the following permits from the United States Department of Agriculture:

Early Intake Camp, 12.83 acres, in Sec. 11, T. 1. S., R. 18 E.
Grouse Springs No. 1 Camp Site, 2 acres, in same section.
Grouse Springs No. 2 Camp Site, 2.8 acres, in same section.
Half Way Camp, Early Intake, 8.25 acres, in same section.

CITY DISTRIBUTING SYSTEM

Pending the settlement of the suit instituted by the Spring Valley Water Company for the adjustment of water rates in San Francisco, realizing that the outlying districts were in urgent need of immediate supply, on the recommendation of this office the Board of Public Works was authorized by Resolution No. 10869 of the Board of Supervisors to sink test holes on property belonging to the City and County in Richmond and Sunset Districts, to determine the feasibility of obtaining a supply from wells in this locality.

Ten test holes were bored and proved the waterbearing possibilities of this district. Contracts were therefore entered into for five wells, the total cost of drilling which amounted to $13,895.94. The cost of the ten test holes amounted to $4,250.25. It is estimated that from the wells already drilled a permanent supply of 1,000,000 gallons a day can be secured. Therefore, if it ever becomes necessary to supply portions of the Richmond or Sunset Districts from this source the necessary pumping station can be installed and distributing reservoir constructed.

Subsequent to the drilling of the wells, however, on July 3, 1915, the following Resolution was passed by the Board of Supervisors (No. 11886 New Series):

> Whereas, The Spring Valley Water Company has submitted in writing an offer to make certain needed extensions to its water mains in the City and County of San Francisco; and
>
> Whereas, One of the conditions of said offer is that the cost of installing said mains shall be added to any price which may be fixed upon the properties of said Company now under condemnation in suit No. 53708 in the Superior Court of this City and County; now, therefore, be it
>
> Resolved, That the City Attorney is hereby authorized and directed to enter into a stipulation in said case with the Spring Valley Water Company to the effect that the cost of such extensions when completed may be added to the value of the properties found by the Court as of the day on which the summons was issued.

Pursuant to this agreement, the Spring Valley Water Company has installed since July 3, 1915, the following pipes in the various districts:

Richmond District.

16″ main in 23rd Ave., from Fulton to Geary Sts.
12″ main in Anza St., 23rd to 29th Aves.
12″ main in 29th Ave., from Anza to Balboa Sts.
12″ main in Balboa St., from 29th to 31st Aves.
8″ main in Balboa St., from 31st to 42nd Aves.
8″ main in 42nd Ave., from Balboa to Geary Sts.
8″ main in Fulton St., from 10th to 23rd Aves.
8″ main in 28th Ave., from Anza to Geary Sts.
8″ main in 21st Ave., from Anza to Geary Sts.
6″ main in 18th Ave., from Fulton to Cabrillo Sts.

These mains are all extensions and connections for service from the 30″ main laid across Golden Gate Park from Lincoln Way and 19th Avenue to Fulton Street and 23rd Avenue, and form extensions to the main arteries for supply into the district previously supplied with a 16″ main in Geary Street extending as far west as 23rd Avenue and north in 23rd Avenue to California Street.

There is a section of this district lying between 9th and 23rd Avenues, and Fulton and Geary Streets, which is served by small pipes, nothing larger than 2″ diameter, excepting for a 4″ pipe running one block south of Geary Street in 11th and 12th Avenues and a 6″ pipe running two blocks south from Geary Street in 21st Avenue. In the section between 23rd and 47th Avenues, between Fulton and Balboa Streets, there are no pipes larger than 2″, and there are no pipe lines in Fulton Street. The nearest supply to this district is the line from 29th to 42nd Avenues in Balboa Street, from which laterals could be run to supply the district. A satisfactory water supply for this district might be made by installing a sufficient number of laterals to cover the sections of the district now not supplied in any manner.

Sunset District.

The Spring Valley Water Company has installed the following:

16″ main in Judah St., from 7th to 19th Aves.
16″ main in 19th Ave., from Judah St. to Lincoln Way, connecting same with the 30″ main across the Park.
6″ main in Judah St., from 19th to 27th Aves.
6″ main in 27th Ave., from Judah to Irving Sts.
6″ main in Irving St., from 27th to 28th Aves.
4″ main in 19th Ave., from Judah to Quintara Sts.
4″ main in Quintara St., from 19th to 10th Aves., into Forest Hill.

In view of possible unforeseen emergencies, it is recommended to make further expenditures in the development of wells in the outlying districts, and it is strongly urged that additional waterbearing land be purchased adjacent to the most desirable well sites. With proper pumping stations installed ready for service, this source would provide the same protection for domestic supply that the high pressure furnishes for fire protection. The City would then have in reserve a dependable supply from this source, but its use at the present time would be inadvisable when it is within the power of the Railroad Commission to compel the Spring Valley Water Company to furnish an adequate supply for all purposes.

EXHIBIT "G"

EXPENDITURES ON THE HETCH HETCHY WATER SUPPLY FROM 1900 TO 1916, AND ESTIMATED ANNUAL EXPENDITURES TO THE END OF THE CONSTRUCTION PERIOD

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1. PRELIMINARY EXPENDITURES, JAN. 1, 1900, TO JAN. 31, 1916, INCLUSIVE

(Round figures used)

1900-1906:	
Engineering expense on preliminary investigations	$ 44,000
1906-1910:	
General and legal expense	$ 9,000
Engineering	14,000
Lands	51,000
Total for period 1906-1910	$ 74,000
1910-1911:	
General and legal expense	$ 26,000
Engineering	40,000
Lands and water rights	537,000
Total for period 1910-1911	$ 603,000
1912-January 31, 1916:	
General and legal expense	$ 60,000
General engineering	45,000
Water supply investigations	320,000
Railroad surveys and construction	200,000
Hetch Hetchy reservoir: surveys, permanent camp, clearing reservoir, construction of diversion tunnel, road, trails, telephone line, etc.	150,000
Aqueduct: surveys, roads, trails, Early Intake portal excavation, etc.	74,000
Lands, water rights, rights of way	697,000
Total for period 1912-January 31, 1916	$1,546,000
Summary for period Jan. 1, 1900, to Jan. 31, 1916:	
General and legal expense	$ 95,000
General engineering	143,000
Water supply investigations	320,000
Railroad surveys and construction	200,000
Hetch Hetchy reservoir, preliminary work	150,000
Aqueduct surveys and construction	74,000
Lands, water rights and rights of way	1,285,000
Total	$2,267,000

2. PRELIMINARY WORK YET TO BE ACCOMPLISHED IN THE FIELD BEFORE ACTIVE CONSTRUCTION WORK ON THE VARIOUS PERMANENT FEATURES OF THE HETCH HETCHY SUPPLY DEVELOPMENT CAN BE STARTED

ALL TO BE CARRIED OUT IN 1916, EXCEPT AS OTHERWISE NOTED

Hetch Hetchy Railroad:

Construction now in progress to be completed in 1916; engineering and payments for rights of way; rolling stock, buildings, etc. $1,650,000

Lower Cherry Power Development for Construction Purposes:

Storage and diversion dams and canals to be constructed in 1916 .. $120,000

Power plant and transmission lines to be constructed early in 1917 so as to furnish power as early as required for dam and tunnel construction 120,000

Total for this power development 240,000

Hetch Hetchy Reservoir:

Clearing of reservoir now in progress and diversion tunnel, now under construction, to be completed; diversion dam, roads and trails and additional camp buildings to be constructed; lower part of foundation of dam to be stripped and river channel below dam site to be cleared, etc. 160,000

Aqueduct, Early Intake to Moccasin Creek:

Geological investigation of aqueduct line (diamond drillings); excavation at portals; roads, trails, camps, etc. 50,000

San Joaquin Valley Pipe Line and Aqueduct Tunnel in Coast Range:

Surveys 15,000

Total cost of above described work $2,115,000

3. PROSECUTION OF CONSTRUCTION WORK FROM 1917 TO THE END OF THE CONSTRUCTION PERIOD

On each of the large divisions of the system the first year of construction will be devoted to the assembling of construction plant and materials and the commencement of work on permanent construction. At the dam this construction will embrace the continuation of the foundation stripping and the beginning of the concrete construction. On the aqueduct tunnels work will be started from the portals and the sinking of shafts will commence during the first year.

The rate at which the work is to be carried on is indicated by the cost figures on the following page. The table on that page also shows the correlation of the various features of the work so as to bring all parts of the system to completion at the same time.

EXHIBIT "G"—Continued

SCHEDULE OF EXPENDITURES FOR HETCH HETCHY WATER SUPPLY SYSTEM

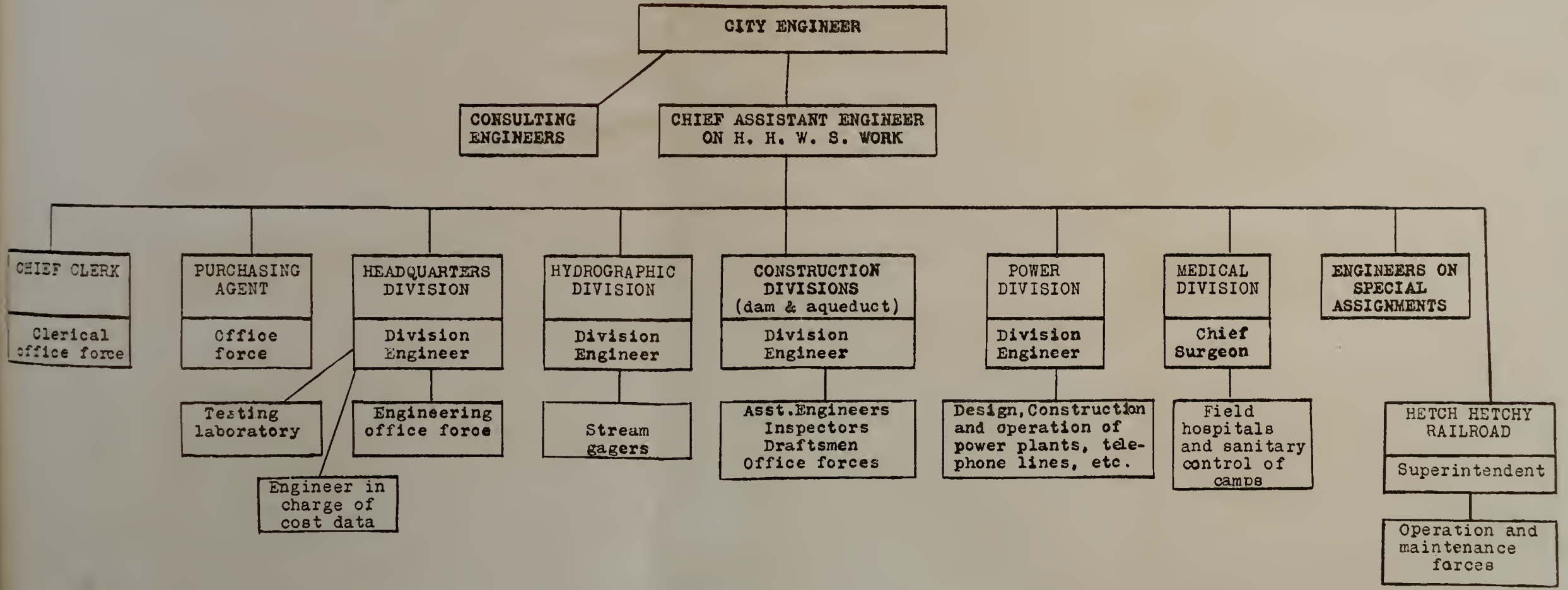
(City Distributing System Not Included)

YEAR	General engineering, legal expense, water supply investigations, hydrography	Lands, water rights, rights of way	Hetch Hetchy Railroad	Lower Cherry Canal and Temporary Power Plant	Hetch Hetchy Reservoir	HETCH HETCHY AQUEDUCT: Tunnel Early Intake to Moccasin Creek	HETCH HETCHY AQUEDUCT: Tunnel Moccasin Creek to east side San Joaquin Valley	HETCH HETCHY AQUEDUCT: San Joaquin Valley pipe line	HETCH HETCHY AQUEDUCT: Coast Range Tunnel	HETCH HETCHY AQUEDUCT: Pipe line Irvington to San Francisco	Moccasin Creek Power Plant, initial installation, 37,500 K. W.	Totals for entire system
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13
1900 to 1915....	$558,000	$1,285,000	$ 200,000	.....	$ 150,000	$ 74,000	.....	.....	.....	.....	.....	$ 2,267,000
1916.....	$ 65,000	$ 25,000	$1,650,000	$120,000	$ 160,000	$ 50,000	.....	$ 5,000	$ 10,000	.....	.....	$ 2,085,000
1917.....	.....	.....	.....	120,000	700,000	750,000	$ 10,000	30,000	125,000	$ 10,000	.....	1,745,000
1918	Expenditures under		Cost of operation and		900,000	1,300,000	40,000	65,000	1,000,000	40,000	.....	3,345,000
1919	these two heads after		maintenance of rail-		1,100,000	1,300,000	150,000	300,000	1,500,000	250,000	.....	4,600,000
1920	1916 are included in		road and power plant		1,140,000	1,300,000	500,000	700,000	2,000,000	700,000	$1,400,000	7,740,000
1921	construction costs of		is included in con-		.....	1,300,000	1,000,000	1,300,000	2,000,000	1,300,000	2,000,000	8,900,000
1922	reservoir, aqueduct		struction cost of res-		.....	.....	1,200,000	1,300,000	3,000,000	1,300,000	.....	6,800,000
1923	and power plant.		ervoir and aqueduct.		.....	.....	1,100,000	1,300,000	3,000,000	1,265,000	.....	6,665,000
Totals	$623,000	$1,310,000	$1,850,000	$240,000	$4,150,000	$6,074,000	$4,000,000	$5,000,000	$12,635,000	$4,865,000	$3,400,000	$44,147,000

EXHIBIT "H"

HETCH HETCHY WATER SUPPLY

TENTATIVE ORGANIZATION OF ENGINEERING FORCE FOR CONSTRUCTION



YEAR	Totals for entire system
Col. 1	Col. 13
1900 to 1915....	$ 2,267,000
1916.....	2,085,000
1917.....	1,745,000
1918	3,345,000
1919	4,600,000
1920	7,740,000
1921	8,900,000
1922	6,800,000
1923	6,665,000
Totals	$44,147,000

EXHIBIT "I"

CONDITION OF HETCH HETCHY APPROPRIATIONS FEBRUARY 4, 1916

Closed Accounts—	Amount Appropriated.	Amount Expended.	Balance.
City Engineer's part salary	$ 5,000.00	$ 5,000.00	.....
Co-operative road work	3,500.00	3,500.00	.....
Hog Ranch Road to Hetch Hetchy dam site	180,943.84	180,943.84	.....
Hydrographic data for government	5,000.00	4,999.70	.30
Investigating sources of water supply, B. P. W.	140,651.29	140,408.29	243.00
Lake Eleanor	45,000.00	25,476.32	19,523.68
Investigating McCloud River project	500.00	500.00	.....
Priest's Hill, construction of roads	2,500.00	2,500.00	.....
Engineer's appraisal of Spring Valley water system	3,500.00	3,500.00	.....
Investigating claims of Spring Valley Water Co. in Alameda County	1,400.00	1,400.00	.....
Boring test holes in Richmond and Sunset Districts	5,137.01	5,137.01	.....
Investigating Turlock and Modesto Irrigation District	500.00	318.90	181.10
Open Accounts—			
City Engineer's investigation of Hetch Hetchy	2,000.00	2,000.00	.....
Clearing Hetch Hetchy Reservoir	43,000.00	17,032.21	25,967.79
Diversion tunnel and diversion dam at Hetch Hetchy	90,500.00	51,061.50	39,438.50
Purchase of gaging apparatus and instruments	5,000.00	1,715.58	3,284.42
General office work, plans, etc.	31,000.00	23,566.58	7,433.42
Hydrography, by B. P. W.	13,000.00	11,031.01	1,968.99
Installing sawmill	13,000.00	12,992.20	7.80
Inspection and engineering in field	8,000.00	6,369.81	1,630.19
Inspection of track material for Hetch Hetchy Railroad	900.00	.....	900.00
Insurance with State Compensation Fund	1,000.00	228.90	771.10
Operating sawmill	14,000.00	12,912.01	1,087.99
Permanent camps and equipment	18,500.00	16,284.92	2,215.08
Roads, trails and surveys	72,250.00	71,665.14	584.86
Surveys, aqueduct location	9,500.00	7,188.92	2,311.08
Surveys, railroad location	8,000.00	7,932.23	67.77
Telephone lines, Hamilton to Hog Ranch or Portulaca, etc.	5,000.00	4,987.56	12.44
Test borings	5,000.00	.....	5,000.00
Timber cut on government lands	1,000.00	452.81	547.19
Water rights and protective work	20,000.00	13,702.93	6,297.07
Drilling wells on City property in Richmond and Sunset Districts	15,997.05	14,534.43	1,462.62
Totals	$770,279.19	$649,342.80	$120,936.39

The above are the various accounts of the 1910 Water Construction Bond Fund, showing the amounts appropriated and expended out of same by Board of Public Works up to February 4, 1916, as taken from the books of the Bookkeeper of the Board of Public Works.

EXHIBIT "J"

APPROPRIATIONS REQUESTED FOR HETCH HETCHY WATER SUPPLY WORK TO BE EXECUTED FROM MARCH TO DECEMBER, 1916

1.	Hydrography	$ 12,000
2.	Surveys, aqueduct, San Joaquin Valley, etc.	15,000
3.	Water rights and protective work	30,000
4.	Test borings on aqueduct line (additional to $5,000 already appropriated but not yet used)	20,000
5.	Headquarters engineering, including consulting engineers, geological studies and general office expense	75,000
6.	Roads and trails	20,000
7.	Inspection and engineering in field	35,000
8.	Permanent camps and equipment	24,000
9.	Operation of sawmill, 1916	10,000
10.	Diversion tunnel and diversion dam	23,000
11.	Foundation work for main Hetch Hetchy dam	52,000
12.	Railroad equipment and buildings	50,000
13.	Lower Cherry power development for construction purposes	100,000
14.	Acquisition of necessary rights of way through privately owned lands	500,000
	Total	$966,000

Appropriations for the construction of the Hetch Hetchy Railroad and the clearing of the Hetch Hetchy reservoir site have already been made.

EXHIBIT "K"

MEDICAL SERVICE, ACCIDENTS TO EMPLOYEES— LOS ANGELES AQUEDUCT

3rd Annual Report (Nov., 1908), p. 58:

The organization of a medical department for and in conjunction with the construction of the Los Angeles Aqueduct, and for the benefit of its employees, was authorized by a resolution of the Board of Public Works. On May 13th, 1908, a contract was signed between the Board of Public Works and Drs. Rea Smith, E. C. Moore, and Raymond G. Taylor, wherein the latter agreed to undertake the organization, equipment and administration of such a Department.

Synopsis of Contract.

The Department is supported by assessments from all Aqueduct employees including those of Contractors and Sub-contractors.

Assessments are $1.00 monthly from those receiving a wage of $40.00 or over per month, and 50 cents from those receiving less. Any employee is entitled to Medical, Hospital and Surgical service when needed, except for venereal diseases, intemperance, vicious habits, injuries received in fights, or chronic diseases acquired before employment.

Hospitals are of two kinds: Field, erected by the city at suitable points, with accommodations for six patients, surgeon and nurse; and General, located in Los Angeles. The city is to provide wagon transportation for supplies from the railroad to suitable points of the work, and wagon transportation for sick and injured on the work, to Field Hospital or railroad.

Meals, food, water, etc., are furnished by the city and its Contractors to the Medical Department at regular rates at the various camps. Gasoline is furnished by

the city at cost, plus 10%. The City grants the use of the telephone and telegraph lines owned and controlled by it.

Contractors agree to furnish and equip Hospitals, provide Physicians, Nurses and Stewards; to furnish drugs, nursing and medical and surgical attention; to furnish board for bed patients in the Field, and all patients in the General Hospitals; to furnish railroad transportation, where necessary, to the General Hospital and return fare, provided patients re-enter Aqueduct service within five days of their discharge from Hospital.

Contractors are empowered to make sanitary inspection and establish quarantine if necessary.

Organization.

In the practical working out of the plan contemplated in the Contract, several additions, with the idea of giving better and more efficient service, have been made.

Three classes of Hospitals have been established: Camp or Tent, Field or Division, and General.

A Camp or Tent Hospital is located in every camp on the work. It consists of a 14x16 wall tent, framed and floored, and is practically wind and rain proof.

Each division is divided into sections.

The Camp Hospitals in each section are in charge of the Hospital Steward, who is provided with a saddle horse and makes daily trips to all camps in the section.

Field or Division Hospitals are located at Division headquarters and, where practicable, on the railroad. They are built of wood, and normally accommodate six patients (the Jawbone Hospital accommodates twelve), Hospital Stewards and Surgeons. They are headquarters for the Division Surgeons, and distributing points for supplies.

The General Hospital is the California Hospital, located at Los Angeles, and all severe cases that cannot be properly cared for in the field are removed to it. Arrangements have been made by the Contractor with the management of the Hospital whereby Aqueduct patients requiring General Hospital care are received and given exactly the same care and attention as any private patient.

Surgeons are of four classes: 1st—Consulting Surgeons, who are Specialists in their various lines. 2nd—Chief Surgeons, in direct charge and management in the Department. 3rd—Assistant or Division Surgeons, in charge of Field or Division Hospitals and tributary Camp Hospitals and Stewards. 4th—Local or resident Surgeons, who, while not located at a Field Hospital, reside in the neighborhood and are subject to call at any time.

Hospital Stewards are located at all Field or Division Hospitals and at such Camp or Tent Hospitals as the necessities of work demand. Their duties are to prepare food, administer the details of treatment and nursing, and give first aid to the sick and injured. They are under the supervision and report to the nearest Division Surgeon.

Inspection and Sanitation.

An inspection trip is made by the Contractors over the whole line of the Aqueduct once a month. Short trips to the principal points on the work are made several times per month, as necessity may require.

Sanitary conditions are inquired into not only on these trips of inspection, but constantly by the Division Surgeons and the Hospital Stewards, who are over the ground daily. Unsanitary conditions of the camps, bunk houses, mess house, commissary, water supply, drains or toilets, if found, are at once brought to the attention of the engineer in charge and immediately remedied. The camps are well policed at this date and in good condition.

Equipment.

Camp or Tent Hospitals are equipped with stoves for heating and simple cooking, and cooking utensils, basins, irrigators, etc., and material for doing ordinary surgical

dressings; medicine chest and medicines; three cot beds with bedding; stretchers for emergency use in case of accident on the work.

Field or Division Hospitals.

Field or Division Hospitals are provided with operating room and appliances for doing practically anything that may be required in the medical or surgical line; a complete supply of drugs and dressings and disinfectants; iron cots with sanitary springs, wool mattresses and bedding; stoves and utensils for heating and cooking; bath tub, slop hopper and sewer connections.

General Hospital.

The General Hospital is one of the best and most completely equipped Hospitals on the Pacific Coast, and all its conveniences and equipment are at the disposal of this Department for the benefit of its patients.

Location of Hospital, Surgeons and Stewards.

Camp or Tent Hospitals have been erected at all the principal camps except those camps having Field Hospitals. About fifteen are in use at present and more are constantly being erected as the work of construction extends.

6th Annual Report (1911), p. 72:

Personal Injuries:

From the beginning of construction work on the Aqueduct to the date of this report, 653 cases of injury to employes have been reported to this department for investigation. This total, however, includes all cases, no matter how slight the injury and regardless of whether or not the employee lost any time by reason thereof. In pursuance of the policy adopted by the Board of Public Works, half pay has been allowed during the period of disability due to such injuries, to 325 of the injured employees, the total amount paid out on such half pay allowances being $12,454.58. In eight cases, the employees have made claim for damages. An aggregate sum of $7,750 has been paid in settlement of such damage claims, and there are three suits for damages still pending against the city growing out of personal injuries received by employees on the Aqueduct.

7th Annual Report (1912), p. 88:

Personal Injuries:

During the fiscal year ending June 30, 1912, four hundred and forty-six (446) cases of injury to employees have been reported to this Department for investigation. This total, however, includes all cases, no matter how slight the injury and regardless of whether or not the employee lost any time by reason thereof. In pursuance of the policy adopted by the Board of Public Works, half pay and settlements to the amount of Eight Thousand Five Hundred One and 4/100 Dollars ($8,501.04) have been allowed as compensation for said injuries.

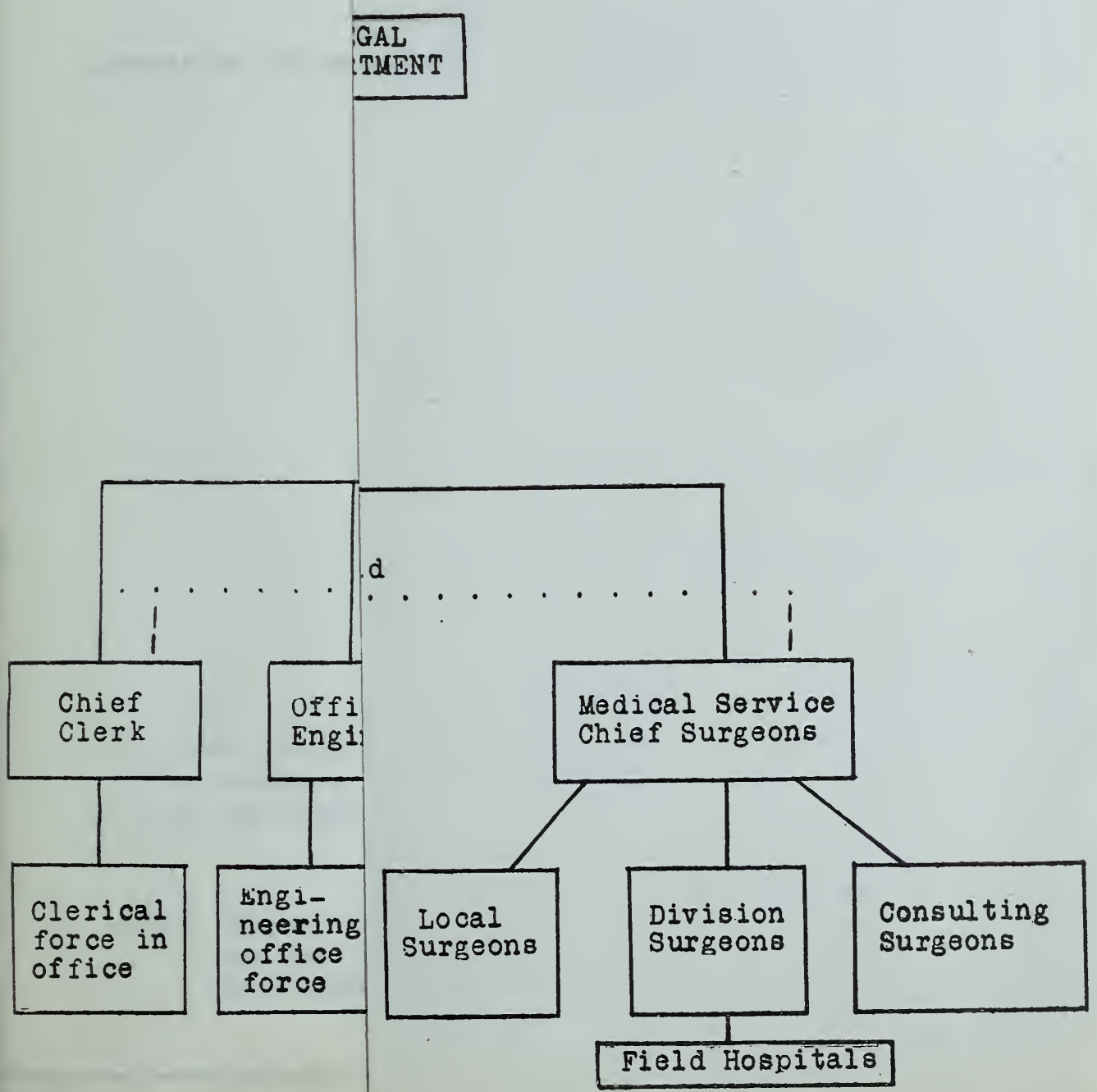


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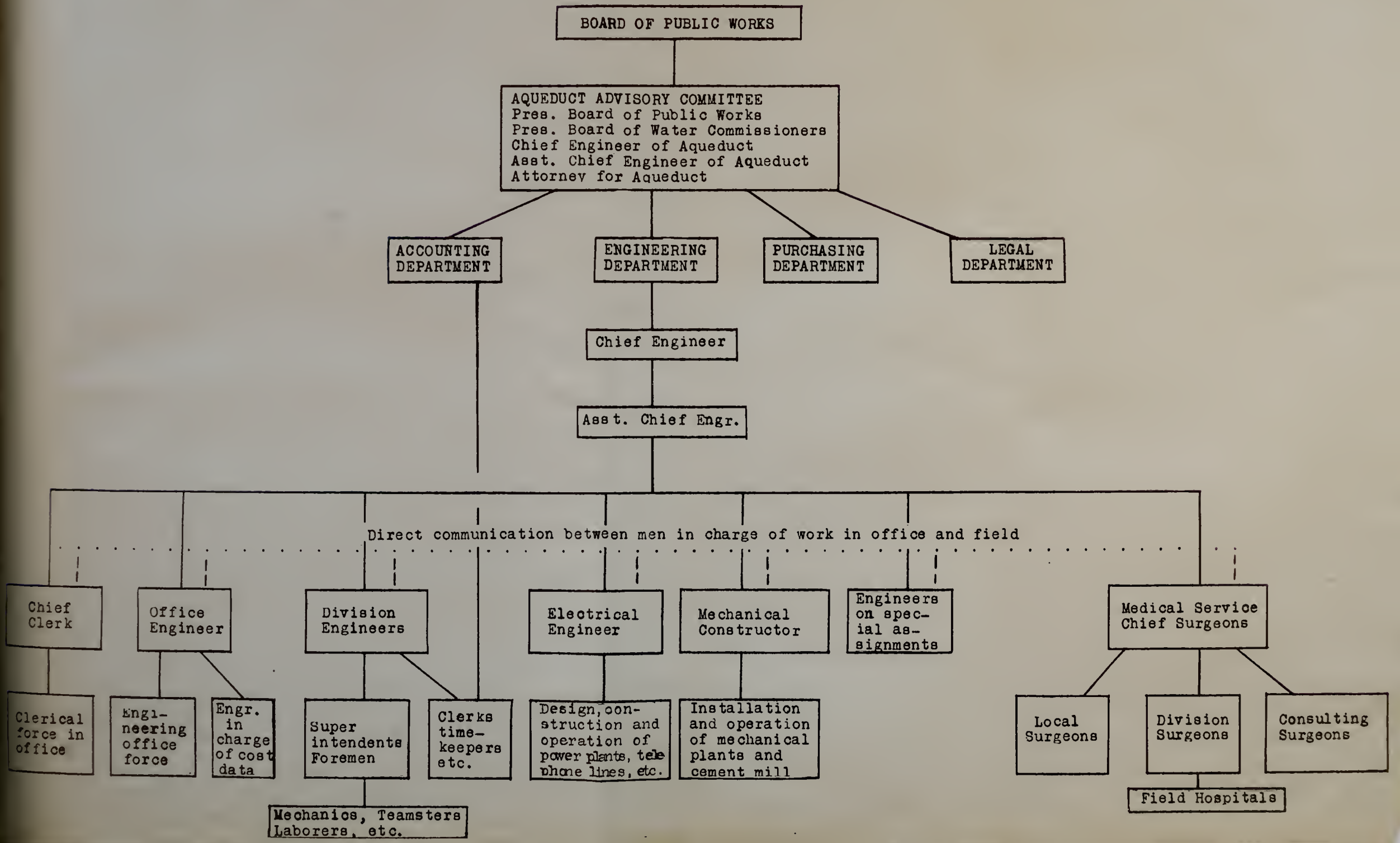
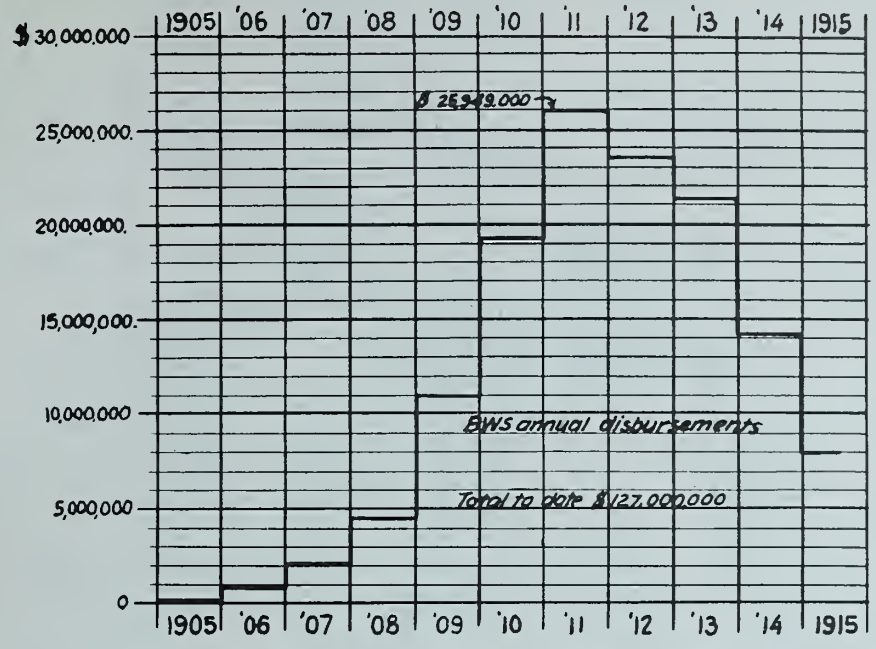
EXHIBIT "L"

LOS ANGELES AQUEDUCT

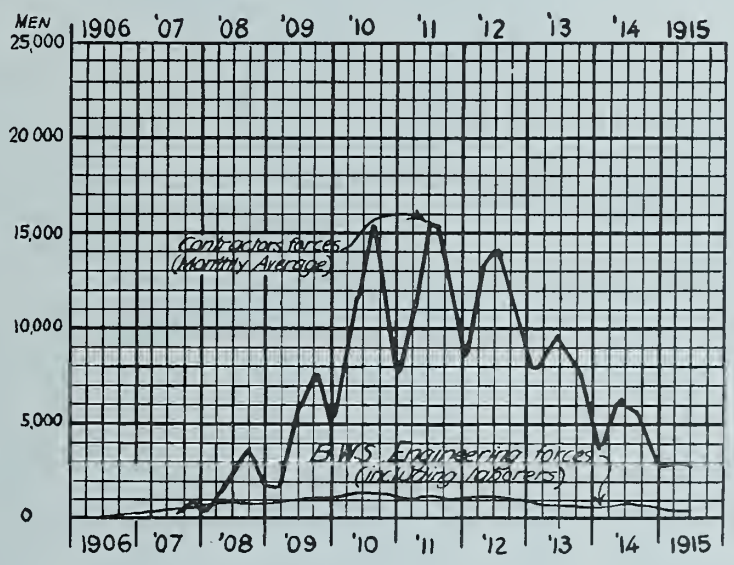
ORGANIZATION OF ENGINEERING FORCE DURING CONSTRUCTION PERIOD





Total estimated cost of Catskill Water Supply $177,000,000

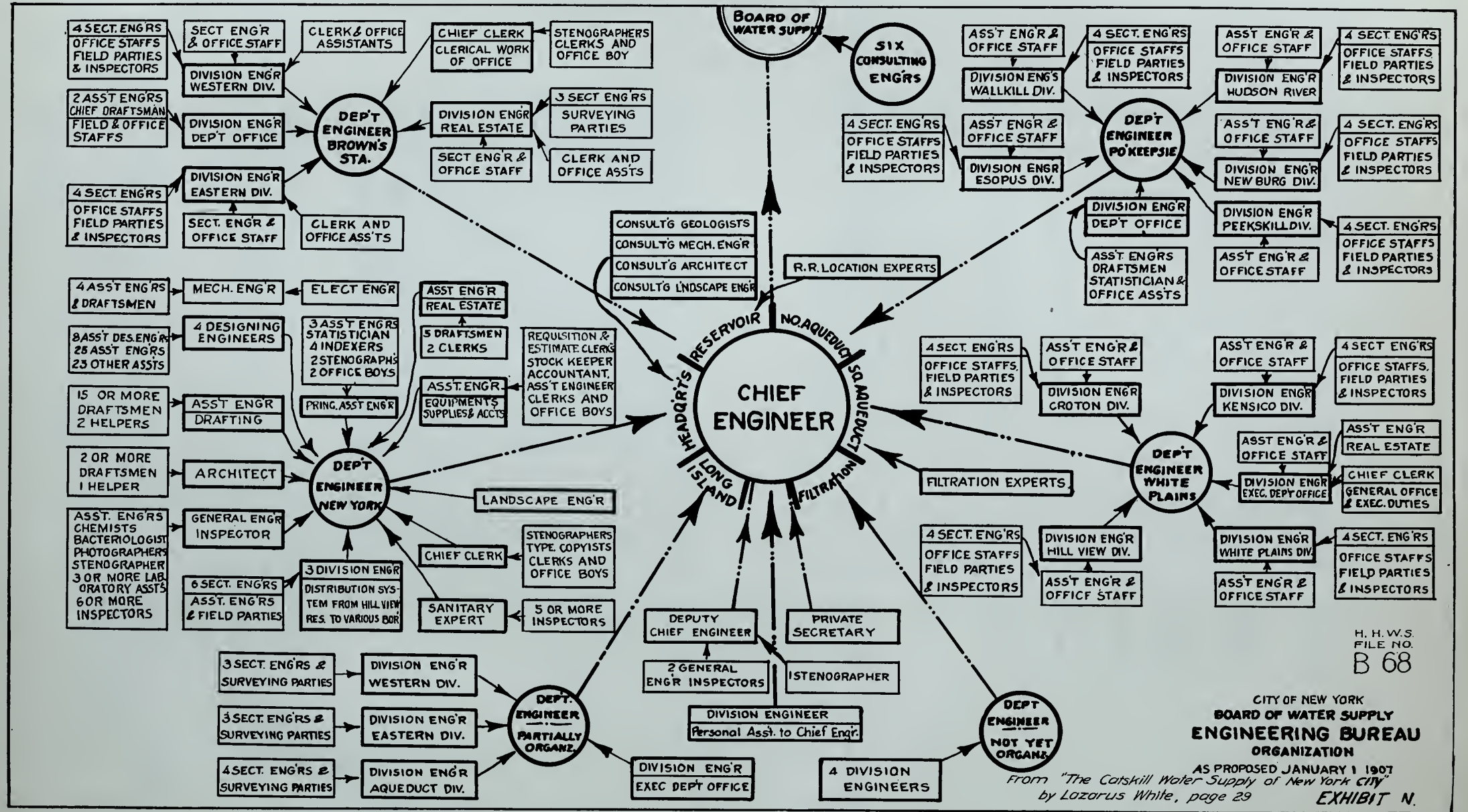
DIAGRAM OF THE ANNUAL EXPENDITURES, TO THE MIDDLE OF 1915, OF THE BOARD OF WATER SUPPLY



This diagram shows the contractors' working force, reaching a maximum of about 17,000; and the engineering force, at the bottom, which reaches a maximum of about 1,325.

Note: Traced from paper "The Present Status of the Castkill Water Supply for New York City," by J. Waldo Smith, Chief Engr., Board of Water Supply, dated September 1915.

EXHIBIT M

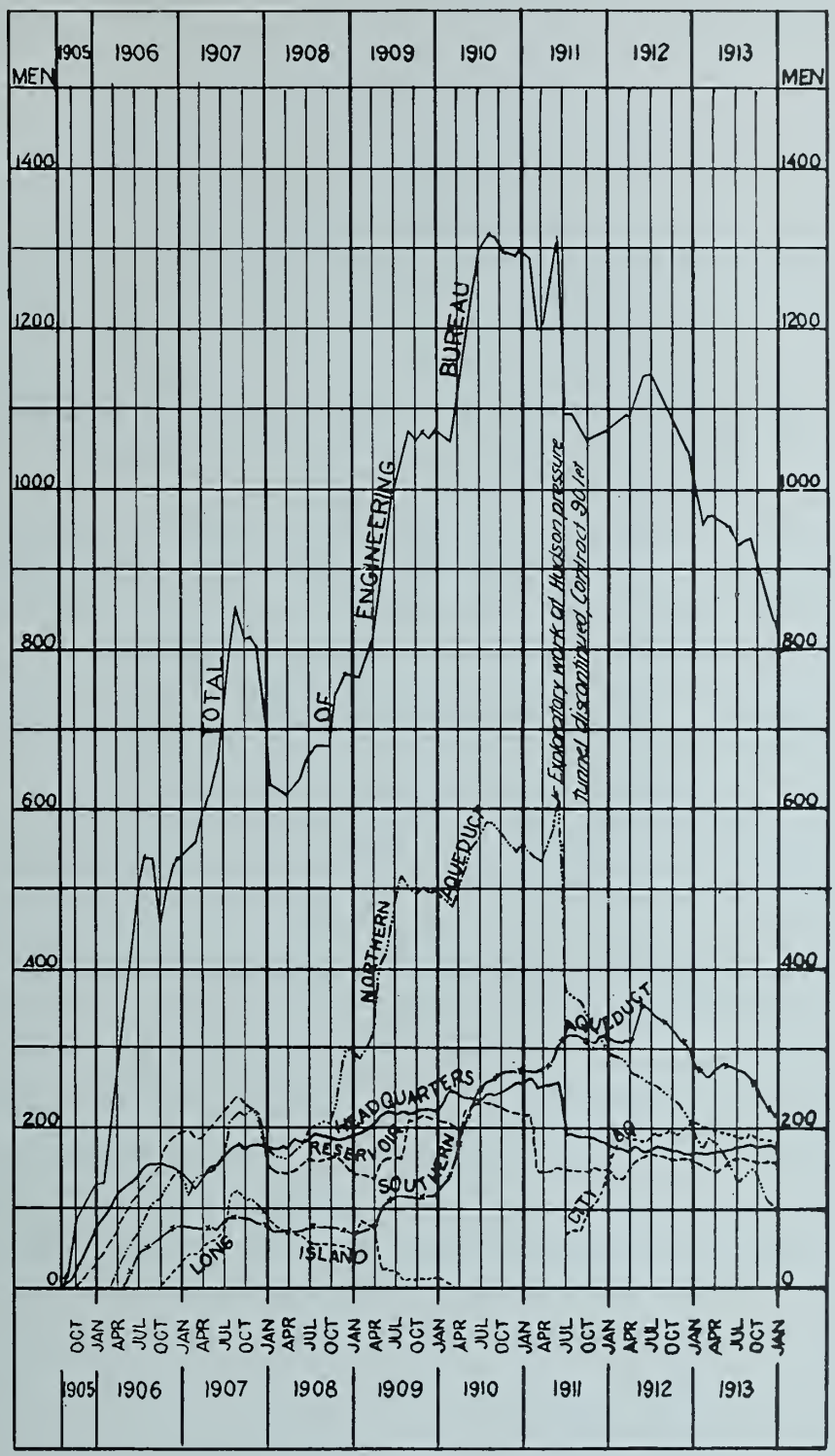


H. H. W. S.
FILE NO.
B 68

CITY OF NEW YORK
BOARD OF WATER SUPPLY
ENGINEERING BUREAU
ORGANIZATION
AS PROPOSED JANUARY 1 1907

From "The Catskill Water Supply of New York City" by Lazarus White, page 29

EXHIBIT N.



CATSKILL WATER SUPPLY OF THE CITY OF NEW YORK,
FLUCTUATIONS IN ENGINEERING BUREAU FORCES.

Note: From 8th Annual Report of the Board of Water Supply.-

EXHIBIT O.

HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF
SAN FRANCISCO, CALIFORNIA.

REPORT OF M. M. O'SHAUGHNESSY
CITY ENGINEER

TO

THE MAYOR, THE BOARD OF PUBLIC WORKS
AND THE BOARD OF SUPERVISORS
OF SAN FRANCISCO

JANUARY, 1917

HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF
SAN FRANCISCO, CALIFORNIA.

REPORT OF M. M. O' SHAUGHNESSY
CITY ENGINEER

TO

THE MAYOR, THE BOARD OF PUBLIC WORKS
AND THE BOARD OF SUPERVISORS
OF SAN FRANCISCO

JANUARY, 1917

San Francisco, January 29, 1917.

To the Honorable, The Mayor,
The Board of Public Works and the
Board of Supervisors of the
City and County of San Francisco.

Gentlemen:-

In my report submitted to the Mayor, the Board of Public Works and the Board of Supervisors, in March, 1916, I outlined a comprehensive plan for the completion of the Hetch Hetchy project.

It affords me pleasure to be able to state that since the filing of said report the work has been actively advanced and the numerous divisions thereof so co-ordinated that a rapid and economical development can be safely predicted for the present year and the subsequent period over which construction will extend.

HETCH HETCHY RAILROAD

For conveying to the site of the Hetch Hetchy dam and upper tunnel aqueduct the 233,000 tons of construction equipment and material necessary for the work, a standard gage railroad was projected and surveyed, previous to 1916.

During the past year grading has been finished for over 80% of the entire railroad, which is 68 miles in length, with a maximum grade of 4% and maximum curvature of 30°. The country traversed is extremely rough but the cost of construction has been very low, due to the care exercised in the location survey.

This railroad extends eastward into the Sierras from Hetch Hetchy Junction (formerly Rosasco), a station on the Sierra Railway of California, 10 miles south of Chinese. The elevation of Hetch Hetchy Junction is 935 feet, from which the railroad after crossing two low ridges drops to 625 feet in a distance of 9 miles to cross the Tuolumne River some 12 feet above extreme high water. From the Tuolumne River, the road is extended to Jacksonville, thence up

Moccasin Creek and Grizzly Gulch to Priest, and thence to Big Oak Flat and Groveland. Most of the climb for eastward traffic toward the dam is on a grade of from 3 to 4 per cent.

Due to the roughness of the country, and since the road is to be operated for freight traffic chiefly, sharp curvature has been frequently used, the maximum being 30°, and curves of from 18 to 26° are numerous.

From Groveland the road continues east past Hamilton Station. Thence it descends to the South and Middle Forks of the Tuolumne River, which will be crossed on ballast deck trestles and finally ascends the Poopenaut Pass where an elevation of 5064 feet is attained; thence a continuous 4% grade descends to the dam site, bench 3869' elevation. This latter stretch of the road, 9 miles in length, was exceedingly rough construction, in many instances having been hewn out from almost vertical cliffs.

Over 1,000,000 cubic yards of excavation were necessary for the railroad. More than half of this was in rock and over one-half million feet of lumber was used for trestling the various small canyons which the road crosses.

For excavation, the material was classified as granite, solid rock, soft rock and earth. Alternate bids were invited for this classification and for payment on the basis of unclassified excavation. It was found more economical to award the contract on the latter basis, 67 cents per cubic yard being paid the Contractor for excavating all classes of material.

For all but the 9 miles descending from the summit of the ridge at Hog Ranch into Hetch Hetchy Valley, the width of roadbed is 16 feet at subgrade. For the last 9 miles the width is 22 feet. Slopes on embankments are 1½ horizontal to 1 vertical.

Ties are of redwood 6 X 8 in. X 8 ft. Rails are 60-pound sections and ballast is 6 inches deep under the ties and must extend 6 inches beyond their ends.

Construction of the railroad was actually begun in February, 1916. An average force of over 600 men has been engaged continuously thereon. Track has been laid from Hetch Hetchy Junction, on the Sierra Railway, to the Tuolumne River, a distance of about 9 miles.

Across the Tuolumne River below Jacksonville, the road will be carried on a steel railroad bridge with a clear span of 220 feet and deck plate girder approaches. The plate girders have a span of 40 feet and are supported by reinforced concrete piers, as is the main bridge structure.

The bridge was supplied to the Contractor by theUnited States Steel Products Company, and was designed according to Cooper's Standard Specifications E-35, to carry two locomotives each weighing 124,000 pounds followed by a uniform load of 3500 pounds per lineal foot of train.

The maximum compressive stress allowed on ties and floor timbers is 1,000 pounds per square inch. The bridge was designed for a wind pressure of 30 pounds per square foot on the exposed surface of all trusses and floor system, in addition to the pressure on a train surface having an average height of 10 feet beginning 2 ft. 6 in. above base of rail. A variation of 150° in temperature was provided for in computing temperature stresses.

This structure is located only a short distance from the Eagle Shawmut gold mine. The fumes from the chlorination works of this property have an exceedingly corrosive effect on steel structures, for which reason the painting of the railroad bridge was not included in the specifications, but will be done directly under the supervision of the City Engineer.

Beside providing for a location which would involve a minimum cost and would be contiguous to all important points of the Hetch Hetchy aqueduct, the line was located with a view of passing through all of the towns which might later furnish freight, in case it was decided to operate the road as a common freight carrier. The wisdom of this course has been strongly emphasized by numerous offers of freight, in case the City cares to handle the same. This subject will be discussed later in the present report.

In April, the State Engineer attempted to compel the City to construct and maintain numerous overhead crossings at all points where the Hetch Hetchy railroad intersects the Tioga (or Big Oak Flat) Road, which was the main county road from Chinese to Yosemite National Park and had recently been acquired by the State from the County. After a vigorous opposition by representatives from the City Engineer's and City Attorney's offices, before the State Railroad Commission, this matter was adjusted to the satisfaction of the City and the position of the City Engineer sustained. Great care will be maintained in operation at all of the crossings and it has been agreed that, at the dangerous one near Stevens Bar all trains will come to a full stop before crossing the road.

Great difficulty has been encountered in securing a right of way over a mining claim on the grade up from Moccasin Creek toward Priest. The claim has been demonstrated by the City's geologists to be of little value but it has been necessary to undertake condemnation proceedings to secure title to the right of way across it. This action has been tried in the Superior Court of Tuolumne County, and the right of way secured for $160. The price asked by the owners of the claim was $100,000.

LOWER CHERRY RIVER POWER DEVELOPMENT

As noted in my recommendation of March, 1916, it had been

determined to erect at Early Intake a temporary power plant for construction purposes. This plant, referred to as the Lower Cherry River Power Development, will generate all of the electric power required for construction purposes for the entire project, from the main Hetch Hetchy dam to Moccasin Creek.

Water for this installation is diverted from Cherry Creek into a conduit of 200 second feet capacity, 3.3 miles long, consisting of 1.4 miles of open ditch, 3 flumes aggregating 1.1 miles, and 5 tunnels aggregating .8 mile. The tunnels have been let by contract to MacArthur Bros. but the balance of the work is being done by the City's forces.

The pressure pipe line connecting the water wheels with the forebay at the lower end of the ditch is 530 feet in length, of 42 inch diameter pipe, ranging in thickness from 3/16 to 3/8 inch.

Water wheels are Francis turbines operating at 720 R.P.M. under a maximum head of 346.5 feet, including a draft head of 15 feet. These turbines are each direct connected to 2300 V., 3-phase, 60-cycle generators, with direct connected exciter. The voltage will be stepped up through a single bank of transformers to 22,000 V. for transmission to the various sub-stations to be located along the 19 miles of aqueduct to the west and at the main Hetch Hetchy dam site 11 miles to the east of the power plant.

To insure sufficient water for operating purposes during the dry season, a temporary dam is required at Lake Eleanor. Due to the assured runoff for the coming season and the light demand for power during 1917, the storage dam at Eleanor will not be required until 1918, but it must be constructed to provide storage during the low water period of 1918.

The site for the temporary storage dam at Lake Eleanor has been changed from that heretofore tentatively selected, due to the

fact that a geological survey of the original site disclosed great depths of gravel and indicated that much excavation would be required to secure proper foundations. This would vastly increase the amount of material required for the dam. It is now proposed to erect the temporary dam at the permanent Eleanor dam site and utilize this temporary dam in connection with the construction of the permanent dam at this point later on.

The dam on Cherry River required to divert the water into the canal has been completed with the exception of installing the head gates, the installation of which has been delayed on account of the hauling conditions to the dam site.

The type of conduit has been modified in many ways from that considered in the construction program for 1916, due to the fact that geological and physical conditions rendered it advisable to construct over 4,200 feet of this conduit in tunnel. This, of course, has required a great deal more time but upon completion will add greatly to the reliability and permanence of the installation. At this date the benching for the canal has been entirely completed and practically 2500 feet of tunnel have been drifted, leaving something over 1700 feet to be completed, which, at the present rate of progress, should be finished on or about March 15. The benching for the flume is practically completed, except at the lower end, where the flume section is to be enlarged to serve as a forebay. Work on the flumes will not be commenced until spring. This construction will be so timed that the completion of the flumes will be accomplished simultaneously with the completion of the canal, power house and tunnels, so that the flumes need not stand without containing water for any length of time.

The excavation for the pressurepipe trench has been completed with the exception of the bell holes and anchorages, which

work will not be done except just in advance of the pipe laying.

Excavation of the power house site is well advanced and being rushed so that the foundations will be in place, ready to receive the machinery as soon as it can be delivered at the power house site.

Due to the unprecedented demand for construction supplies throughout the country affecting the delivery of materials and equipment, it was necessary to enter into contracts for the delivery of all of the hydraulic and electrical machinery during the past year, in order to insure delivery when required. Therefore it was deemed advisable to enter into a great many more contracts during 1916 than was considered necessary in the early part of that year, and moreover this machinery and equipment has been purchased at from 15 to 25 per cent under the present prices.

The status of these various contracts is elsewhere noted under the general head "Contracts".

HETCH HETCHY DAM AND RESERVOIR

At its lower end, Hetch Hetchy Valley narrows to a gorge about 140 feet wide at ordinary low water level (elev.3500) and 720 feet wide at the elevation of the crest of the proposed main dam (elev.3812). All external geological evidence and previous engineering reports and studies indicated that the greatest depth to bedrock below the bed of the stream would be about 40 feet. However, before sinking the cofferdam for the diversion structure, the City Engineer had wash borings made to determine the exact position of the underlying rock. Several of these borings penetrated the gravel and clay in the riverbed to a depth of over 100 feet without reaching rock in place.

Irrespective of the depth to which excavation for the foundations must be carried, the main Hetch Hetchy dam must be built on

solid bedrock. For a structure of the temporary character of the diversion dam, however, whose only purpose is to direct the Tuolumne River through a tunnel past the dam site, while the main dam is being built, it is unnecessary and would be uneconomical to carry the foundations to a depth greater than 50 feet. It would be inadvisable, however, to hasten the diversion structure to completion without taking every precaution to insure its stability. The adverse conditions at the dam site necessarily make this work slower than was anticipated.

After the completion of the cofferdam, the underlying material will be carefully and thoroughly grouted, and a cutoff wall of steel sheet piling driven to bedrock across the upstream side of the diversion dam. Concrete pouring will be started as soon as the coffer dam is completed and will be carried to the level of the stream before the spring freshets, unless unforeseen contingencies hinder operations. The superstructure above stream-bed elevation will be built after the river elevation has sufficiently lowered in the late summer. It will be more economical to delay this latter work until that time, when the railroad will be in operation and the cost of transporting cement to the dam site materially lessened.

The diversion tunnel, partially completed during 1915, was finished during 1916. The diameter of the bore is 20 feet and its length 457 feet. The work was started with hand drills, but air drills driven from a compressor were used for the greater portion. The rock traversed is a very hard granite, and a large portion was saved for use in the concrete of the diversion dam. The cost at which this tunnel was finished proved very satisfactory, being approximately $5. per cubic yard of rock excavated.

Beside the construction of the diversion dam, the work at the damsite will be confined to making extensive core borings in the

riverbed in order that there may be available an exact geological chart on which to base final decision as to the problem of the foundation of the main Hetch Hetchy dam.

Contract for exploring the dam site with drill borings was awarded to the International Diamond Drill Contracting Company on January 5, 1917, for the estimated sum of $14,675.

These borings must be completed within 120 days after the date of signing the contract. On the basis of the data obtained, the design and specifications for the main Hetch Hetchy dam will be completed, and a contract for its construction awarded probably during the present year. The cost of this structure has been estimated at approximately $4,000,000.

The easterly boundary of the Hetch Hetchy watershed extends along the summit of the Sierras for a distance of over 40 miles. Most of this region is of granitic formation, devoid of soil or vegetation. In this area are the head waters of the Tuolumne, whose course is in a northerly direction to the Hetch Hetchy Valley, which on completion of the main dam will be San Francisco's principal storage reservoir, with a capacity of 112 billion gallons.

Unlike the surrounding mountains, portions of Hetch Hetchy Valley itself were densely forested. The entire reservoir area must be absolutely cleared of vegetation before water for domestic purposes can be impounded. That portion of the valley that will be flooded when the diversion dam is completed in 1917 has already been cleared.

Specifications for this work provided that all standing trees, brush and shrubs on the specified area would be cut down and either used for saw logs or cordwood, or burned. Oak, cottonwood, alder, maple and willow were cut and piled as cordwood, at a price of $2.95 per cord. All softwood, including cedar, yellow pine,

sugar pine and red fir, which were over 6 inches in diameter at the butt and which were considered suitable for saw logs by the City Engineer, were cut into 16 foot lengths or longer, peeled, left on cedar skids in piles of 5, 10, 15 or 20, at a cost of $2.20 per M ft. B.M., and when the reservoir is flooded will be floated to the dam site and sawed into logs. Softwood less than 6 inches in diameter at the butt, or for any cause not suitable for saw logs, is cut into cordwood in the same manner as the hardwoods, at a price of $2.45 per cord. All brush and timber not suitable for cordwood or logs is piled and burned. In this manner, 808 acres have been cleared at a cost of approximately $50,000.

CANYON RANCH SAWMILL

Sawmill work for the year was begun on April 23. During the first months of the season, the mill was not run, the operations consisting of felling trees and yarding the logs. The sawmill has been run continuously for the whole summer and there have been manufactured over 1,600,000 board feet of rough lumber, beside a considerable quantity of surfaced material.

Three hundred and twenty acres of additional timber land known as the Dudley property and lying adjacent to the Canyon Ranch, were purchased by the City and it was proposed to cut about 4,000,000 feet more from this land. An agreement has been made with the Department of the Interior, however, whereby any or all of this 4,000,000 feet can be cut from selected trees standing on Government land close to the present mill. This will prove a great convenience to the City, and will also preserve the beauty of the surrounding forests, by permitting of scattered trees being taken from a wider area and consequently no one particular spot will be entirely denuded. The U.S. Government will obtain the fee title to this land and the remaining uncut timber when the City's operations are completed, in full com-

pensation for all timber cut on government land surrounding Hetch Hetchy Valley.

GROVELAND OFFICE BUILDING

At Groveland, an office building has been erected to serve as main headquarters for all work in Tuolumne County. This is a two story, frame structure, with rooms for offices, drafting, blueprinting, small store rooms and some living quarters. A steam heating plant has been installed as the winter weather in Groveland is very severe. The cost of the building and equipment amounted to $5740., and the cost of the adjacent warehouse was $800.

WATER RIGHTS AND PROTECTIVE WORK

Work has been continued on the bench for the aqueduct from the Early Intake diversion dam to the portal of main tunnel of Hetch Hetchy aqueduct. This bench is now in temporary use as a road, in connection with the Lower Cherry development work.

The construction of the Early Intake road has been continued to the camp near this tunnel portal and a highway bridge with with an 80 foot span has been erected across the Tuolumne River. This road at present extends to the Lower Cherry power house and to the aqueduct, but will ultimately be continued to the confluence of Cherry and Tuolumne Rivers, and thence up the Cherry to Lake Eleanor and Cherry Valley.

Work has been done on the road and ditch at the Middle Fork Homestead (the Dyke Place); also ditch work and road work, to hold the City's water rights on the South Fork near the main Tuolumne.

A new road has been started from Hetch Hetchy Valley to Lake Eleanor. This will be about 9 miles long and in December, 1916, when snows forced the temporary cessation of the work until next spring, 5 miles had been constructed. It will be built on a 12 per cent grade

with a 10 foot roadbed. From a point near Hetch Hetchy dam site, it climbs the steep cliffs on the northerly side of the valley by a series of "switchbacks" to over 5300 ft. elevation, then descends via McGill Meadows to Lake Eleanor. The primary use for which this road is intended is the present transportation of material to the Lake Eleanor Dam, to be built as a part of the Lower Cherry power development, as well as for use during the construction of the main dam at Lake Eleanor, in the future.

Work has begun on a road along the south side of Hetch Hetchy Valley, as required in the Hetch Hetchy Grant.

It has been necessary for the City in order to keep its activities continuous, to assist materially in the maintenance of the roads from Chinese to Hetch Hetchy Valley, as neither the State nor Tuolumne County seem to be able to maintain them in reasonably good condition for heavy traffic.

STREAM MEASUREMENTS

Hydrographic and meterologic observations have been continued at Hetch Hetchy, Lake Eleanor and Cherry Creek.

The hydrographer who has heretofore lived in Hetch Hetchy Valley is to be moved to the junction of South Fork and main Tuolumne Rivers, where a new cabin is being erected. The gage at Hetch Hetchy Valley will hereafter be read by one of the assistant engineers on construction.

New gaging stations have been built on South Fork and on Middle Fork of Tuolumne River. In construction of the aqueduct for Lower Cherry power house, the diversion dam has been so made that it can be used as a weir, by this means enabling us to secure reliable runoff records of Cherry River, which is the combined flow of Cherry and Eleanor Creeks.

HETCH HETCHY AQUEDUCT SURVEY

During the past year, the aqueduct survey has been extended on the ground from the Oakdale Portal in Sierra foothills to the San Francisco terminal at the University Mound Reservoir, a distance of 118.66 miles, lengthening the distance in the Freeman report by two miles. This is the first accurate survey that has ever been made of the entire aqueduct line for the revised project.

From Hetch Hetchy Reservoir to Early Intake, a distance of 12 miles, the riverbed of the Tuolumne will temporarily serve as a conduit, until such time as the necessity for the generation of additional power will justify the construction of a tunnel from Hetch Hetchy dam site to a forebay above Early Intake.

From Early Intake to Priest Reservoir, a distance of 18.2 miles, the survey was completed previous to my report of March, 1916, but after further study of the rock formation, by test borings, the location was amended this year. For this entire distance, the aqueduct will be in tunnel, except where the South Fork of the Tuolumne River is crossed with concrete-lined steel pipe.

From Priest Reservoir to Moccasin Creek power house is 1.9 miles.

Another tunnel 5.75 miles in length will extend from Moccasin Creek to Red Mountain Bar, where the Main Tuolumne River will be crossed with a short steel pipe. Thence a tunnel 11.4 miles in length will lead to Oakdale Portal, on the easterly side of the San Joaquin Valley.

From Oakdale Portal (about 4 miles southeasterly from the town of Knights Ferry), the commencement of the present survey, to Tesla Portal on the west side of the San Joaquin River, (about 8 miles southeasterly from Tracy), the aqueduct will consist of 45.2 miles of steel pressure pipes. The thickness of the steel pipe, and hence the

cost, is practically proportional to the water pressure, therefore the pipe line was located on the highest ground immediately adjacent to the direct or shortest line to be followed.

Across the thickly populated Oakdale and Modesto irrigation districts, the location has been such as to offer the least damage to the valuable lands and crops, in case of a break in the pipe line.

The San Joaquin River crossing has been selected so as to permit of structures offering the greatest safety during the annual overflow of the San Joaquin River. This intersection fortunately lies practically on the most direct line of the aqueduct, and although not considered in previous studies, is found to be the shortest crossing. The aqueduct will be carried under the river in a submerged pipe line and the lower areas adjacent to the San Joaquin, subject to overflow during the annual floods, will probably be traversed by means of pipe lines on substantial reinforced concrete trrstles.

Through the Coast Range from Tesla Portal to Irvington Gate House except for a small steel siphon crossing the Alameda Creek channel, the aqueduct will consist of tunnels aggregating approximately 31 miles in length. This section has been the subject of close geological study and the surveyed location made follows what is at present considered the most feasible route avoiding fault lines and rock of uncertain character. The location for the route 6 or 7 miles immediately west of Tesla Portal is as yet uncertain. For this portion, several alternative lines were surveyed and final selection must be based on more definite knowledge, to be obtained by test holes which will be sunk along the several routes.

From Irvington Gate House westerly, the aqueduct will again consist of steel pressure pipe 19.1 miles in length, following practically a straight line from the Gate House to Dumbarton Straits.

where the Bay crossing will be made by means of submarine pipes.

The line thence parallels the Southern Pacific Railroad, through the southerly portion of Redwood City to what is known as the Redwood City Portal, 2 miles westerly from the town of Redwood. Here the aqueduct will consist of tunnels, extending about 1½ miles westward from the Redwood City Portal to the main ridge between San Francisco Bay and Crystal Springs and San Andreas Lakes of the Spring Valley Water Company.

From this point, the tunnels will follow beneath this main ridge to a point about one mile southwesterly from Baden Station. Here the waters will again enter a short steel siphon, across the low area lying between the main Coast Range and San Bruno Mountain to the San Bruno Portal immediately south of Holy Cross Cemetery and about 500 feet east of the Foothill Boulevard. From the San Bruno Portal to University Mound Reservoir will be in tunnel.

The location of the route has been made in the light of careful engineering studies, the controlling considerations being the permanence of the necessary structures, and the safety of the same, commensurate with reasonable economy.

With our source of water supply over 150 miles from the City, great care must be exercised to guard the aqueduct against possible interruption of service, due to any contingency whatsoever. Tunnels intelligently located and properly built will last for all time. Moreover, the expense of construction, in comparison with high pressure pipe of large diameter, is not excessive, when the cost of wide right of way for the latter is considered. Based on a comprehensive geological study of all practical routes, tunnels have been located in stable rock formations, as far as possible, free from the menace of earthquake faults.

The surveys, and levels accompanying the same, have been

very accurately made, great care being exercised throughout to insure the reliability and accuracy of the final results. All portions of the line have been checked by means of triangulation, levels have been checked with U.S. Geological Survey bench marks, and all property lines traversed by the route have been measured and the records of ownership, etc., have been compared with County records, so that when the mapping is completed, necessary data will be at hand for the acquisition of the right of way.

MISCELLANEOUS SURVEYS

Hetch Hetchy Railroad: The employment of six surveying parties was necessary during the construction of the Hetch Hetchy Railroad. Engineers under the direction of this office have set all construction points for the railroad work, have located all structures, cuts, fills, and made all estimates of work done. These parties also give general supervision and make inspection of culverts, trestles and all material received for use on the railroad. Relocation of the line through Drew Reservoir and Jones Reservoir of the Yosemite Power Company was made during June. It is highly problematical whether these reservoirs will ever be constructed, but it was considered desirable so to locate the line that it would entirely avoid them and thereby remove any objections of that company. Due to the completion of most of the railroad grading, the services of two surveying parties recently have been dispensed with.

APPLICATIONS TO DEPARTMENT OF INTERIOR

Under the conditions of the Hetch Hetchy Grant, it was necessary that the City file application maps for all rights of way, etc., to be used in connection with the Hetch Hetchy project within 3 years of the signing of the Grant, by the President on December 19, 1913.

During the year there were filed with and approved by the Department of the Interior the following maps:-

Lower Cherry Aqueduct, dam site and power house site, filed April 14, approved June 22;

Priest Regulating Reservoir and lands necessary for its protection from contamination, filed May 16, approved June 22;

Amended Hetch Hetchy Tunnel Aqueduct from Early Intake to vicinity of Hamilton Station, filed July 3, approved September 12;

Road from Hetch Hetchy Valley to Lake Eleanor, filed October 14, approved December 30.

The following 12 maps were filed December 13, and approval thereof is still pending:-

Hetch Hetchy aqueduct and transmission line from Priest Reservoir to Red Mountain Bar;

Amended location, Lower Cherry aqueduct and Lower Cherry power plant;

Road from Hamilton Station to Lake Eleanor, portion within Stanislaus National Forest;

Road from Hamilton Station to Lake Eleanor, portion within Yosemite National Park;

Railroad yard, gravel pits, spur tracks and tramways near Smith Station;

Camp and quarry sites and railroad loop at Hetch Hetchy dam site;

Road from Jones Station to Early Intake and junction of Cherry and Tuolumne Rivers;

Amended Hetch Hetchy aqueduct from Hamilton Station to Priest Reservoir;

Road from Lake Eleanor to Cherry Valley;

Early Intake diversion dam site, aqueduct line, power plant site, pressure pipe and tunnel line, and electric transmission line;

Electric transmission lines from Early Intake to Hetch Hetchy, Lake Eleanor and Cherry Valley and from Early Intake to Moccasin Creek;

Hetch Hetchy tunnel aqueduct through section 4, T.4 S., R.4 E., a portion of the Coast Range tunnel near Carnegie.

THE OPERATION OF THE HETCH HETCHY RAILROAD

In view of the fact that the Hetch Hetchy Railroad will soon be ready to transport materials from the Sierra Railway to the Hetch Hetchy dam and to intermediate points along the Hetch Hetchy aqueduct, it is essential that arrangements be made in the near future for the operation of the line.

The railroad passes through forests of great extent which have not as yet been touched by the lumber men because of their remoteness from any cheap means of transportation which would enable them to market their products.

The same trains which haul materials eastward to the City's works will be able to haul the products of these forests westward, with little inconvenience to the City's business, and any profits from this hauling should be applied to reduce the net cost of the Hetch Hetchy project an appreciable amount. It is therefore planned to operate the railroad as a common carrier.

SUMMARY

It is estimated that 233,000 tons of freight will be hauled during the construction period, for the first units of the City's system in the Sierra foothills, which is assumed to cover the four years from 1917 to 1920, inclusive.

The heaviest traffic will occur in 1918 and 1919, with over 75,000 tons in each of those years, requiring a daily haulage of 320 tons.

OPERATION BY A PRIVATELY OWNED RAILWAY COMPANY

It has been proposed that instead of operating the railroad with a force employed directly by the City, the operation of the line be entrusted to the Sierra Railway Company, the Southern Pacific Company, or the Atchison, Topeka and Santa Fe Railway Company, under

an agreement which would work out to the advantage of both parties.

Each of these companies has already a railroad operating organization, fully equipped for handling railroad business, and by placing the Hetch Hetchy line under this management, subject to general supervision by the City's own officials, a co-ordination of labor and an avoidance of duplication in the operating staff and equipment could be effected, which might result in the saving of considerable money, especially during the periods of light traffic, when the overhead costs for separate operation would bear a much higher proportion to the total costs. The City would also be relieved from the necessity for making any outlay for equipment and the investment by the private company for new equipment would be relatively small, as much of the necessary rolling stock would be furnished from that which it has already on hand.

If the road is to be operated by any of the above named companies, the conditions would be as follows:-

The City Engineer of San Francisco would act as General Manager and the Second Assistant City Engineer as Assistant Manager. The City would employ the accounting force and the station agents, in order to keep account of the traffic passing over the road, and to check up the cost of operation. The City would also pay the per diem charge for hire of equipment.

The existing administrative staff of the operating company would have the immediate supervision of the operation of the Hetch Hetchy Railroad. This would add very little to the expense of administration already paid said company.

All employes required in the various operating departments would be employed by the contracting company. This covers section gangs, bridge and building maintenance men, machinists and other shop men, train crews, enginehouse employes, train dispatcher, etc.

The operating company would furnish all necessary locomotives and other rolling stock, fuel oil, and other supplies, would maintain the equipment, and would be liable for loss and damage to freight and for accidents of any description.

A tentative suggestion as to the compensation to be paid for these services is that the City should pay the wages of all employes engaged in the maintenance of the H.H.R.R. and in the hauling of trains over the City's rails; the wages of shop men engaged in making ordinary repairs to rolling stock used on the Hetch Hetchy line and the cost of all necessary materials and fuel. In addition to the compensation for this direct cost, the City should pay some proportional figure, possibly about 10% of the direct cost, which will cover general administrative expense, legal expenses, insurance, accidents, claims for loss and damage, and profit.

AMORTIZATION OF COST OF ROAD

The rates charged for transportation should not only cover the expenses of operating the road but should also, in the final summation, pay the cost of constructing and equipping the road (less salvage value at the time its usefulness to the City ceases), as well as interest on that cost.

Depreciation of equipment is charged as an operating expense and should not be included in figures on amortization. For the purpose of estimating transportation rates it is assumed here that one-tenth of the cost of the road, less the items having salvage value, is amortized annually, being repaid to the City in the form of freight rates.

I N T E R E S T

Interest at 4½% per annum on the net amount invested in road and equipment should also be covered by the rates. The term "net amount invested" is here used to designate the total original invest-

ment less the accrued amortization charges. It would obviously be inconsistent to charge interest on money already repaid.

The original investment is $1,850,000, and the annual amortization charge is taken at $165,000, which will be deducted at the end of each year to determine the "net amount invested". The interest charge for the first year will be 4½% on $1,850,000; for the second year, 4½% on $1,685,000, etc.

FREIGHT AND PASSENGER TRANSPORTATION RATES

In order to make the railroad self-supporting, paying all costs of operation and maintenance, interest on cost of construction and equipment, and amortization of cost of construction, it has been estimated that it will be necessary to charge for transportation at the following rates:-

Passengers - 7½ cents per mile
Freight - - -15 cents per ton-mile

On this basis, the tariff charged for transportation of a ton of freight from Hetch Hetchy Junction to Hetch Hetchy dam site would be $10.15 and the passenger fare $5.

In the figures here presented no account has been taken of the possible development of freight traffic other than the hauling of construction materials. To fix a rate for the hauling of lumber for private parties, due consideration must be given to all the elements bearing on the cost.

HIRE OF EQUIPMENT

Practically all freight hauled over the Hetch Hetchy Railroad will be hauled in the same cars in which it is shipped from the points of manufacture or other points at which it is loaded on to cars. A charge per car-day will be made against the road for the use of the cars. The per diem charge under present rules is 75 cents, irrespective of the class or capacity of the freight car. The amount

is charged under an agreement as to interchange of cars between carriers which went into effect September 1, 1916, and terminates May 1, 1917, at which time a new rate is to be fixed, not to exceed $1.25 per day. Prior to September 1, 1916, the rate was 45 cents per day. There is no means of predicting whether the present rate will remain in effect or a higher or lower rate take its place. The present estimate is based on the existing rate.

The Hetch Hetchy Railroad could be operated by the City under the immediate direction of the City Engineer, unless an arrangement more economical and satisfactory to the City is advanced by one of the railroads above named. In any event, its operation and policies must be absolutely controlled by the City.

DEVELOPMENT PROGRAM - 1917

HETCH HETCHY AQUEDUCT

On the basis of the information obtained from the core borings along the aqueduct route, specifications are now being prepared for the construction of a tunnel approximately 19 miles in length, from Early Intake to Priest Regulating Reservoir near Moccasin Creek power house. Bids will probably be invited for the construction of this tunnel in separate units during the present year. The cost for the entire distance from Early Intake to Moccasin Creek will be approximately $6,000,000.

Explorations have been made for the most suitable sites for shafts and adits, and electric lines have been projected to supply all of these points with the necessary power.

The construction of this tunnel will take between four and five years. It will probably be awarded in units of about five miles, under four separate contracts.

The plans proposed by John R. Freeman called for a pressure

tunnel from Early Intake to Moccasin Creek power house, with a surge chamber located on the range above the power house.

I have seen fit in the interest of economy and efficiency of operation, to change this plan, making a forebay reservoir on the hillside above the Moccasin Creek power house and allowing the water to pass through the tunnel at a very moderate pressure. Another change, the desirability of which I am investigating, may be to enlarge the diameter of the aqueduct tunnel and omit concrete lining where the rock is of a dense crystalline nature. Most of the formation through which the tunnel passes is capable of standing premanently without the support of a lining, whose only purpose would be to increase the tunnel capacity by reducing the loss of hydraulic head, due to friction. The same result can be accomplished by enlarging the tunnel section. The question, therefore, resolves itself into one of cost and the determination of the type to be adopted depends upon which is proved by analysis to be more economical.

HETCH HETCHY DAM

When the complete data obtained from the core borings, now in progress at Hetch Hetchy dam site, has been analyzed, specifications for the main dam will be completed and bids for the construction invited. The cost of this structure will be approximately $4,000,000. It is proposed to proceed with the construction of the foundations and the main structure during the current year.

LOWER CHERRY POWER DEVELOPMENT

The completion of the Cherry River diversion dam and appurtenances, the lining of aqueduct tunnels with concrete, where the material is not self-sustaining and the construction of the remainder of the aqueduct and flume for the Lower Cherry Power Development, as well as the construction of the power house, installation of the

hydraulic machinery and transmission lines, are included in the program for the coming summer.

Besides, the Lake Eleanor dam must be constructed to store enough water for the operation of the power house during two or three months of the dry season.

In estimating the cost of the storage dam, I have considered various types, both the gravity, the arch and the multiple arch, but as yet have made no decision as to which is best adapted to the conditions existing at the Eleanor dam site. For a gravity dam, the cost will be approximately $270,000. For the other items above mentioned, as well as for hauling, etc., the cost of the work to be completed this year will amount to approximately $230,000. so that for the completion of the entire Lower Cherry Power Development, $500,000. should be appropriated.

SAWMILL OPERATION

The City's sawmill will be operated during 1917 on a larger scale than during the past two seasons, in order to provide timber for the forms of Hetch Hetchy dam, flume, buildings and miscellaneous construction. It is estimated that the cost of maintenance and possible extensions for the present year will amount to $30,000.

T R A M W A Y

In connection with the construction and operation of the Lower Cherry power plant and the construction of the aqueduct tunnel from Early Intake, it will be economical for the City to construct a tramway between the power house in the canyon and the nearest point of the Hetch Hetchy Railroad on the ridge. The length of this tramway will be approximately 3500 feet, and the cost has been roughly estimated at $20,000.

OTHER CONSTRUCTION

Work will be continued on the road from Hetch Hetchy dam site to Lake Eleanor, and a trail will be built around the Hetch Hetchy reservoir above the level to be flooded by the diversion dam. Other small branch roads will be constructed to give ready access to various portions of the tunnel aqueduct, in order that contractors may haul to the adit locations all of the material required for the tunnel construction. It is estimated that the amount of money necessary for construction of these and other projected roads will amount to $50,000.

To determine which of the alternate routes for the tunnel aqueduct through the Coast Range will be most economical, core borings must be made. Six Thousand Dollars should cover the cost of this investigation.

The work of clearing the bottom of Hetch Hetchy Valley to the 3560 foot contour, was practically completed during 1916. It is deemed advisable to start the clearing of the higher levels of the reservoir by day labor, under the direction of the City Engineer. For this work $30,000. will be required.

In order to direct the construction work expeditiously, it will be essential that a direct telephone line be at the disposal of the City Engineer, connecting the City Hall office with Groveland headquarters. A switch board will be located in the Groveland office so that a through telephone connection can be had from the City Hall to any portion of the work. The movement of freight over the Hetch Hetchy Railroad will also be facilitated by a direct line to the City. The cost of leasing a direct wire from Groveland to San Francisco will amount to $4500 per annum.

If no operating arrangement is perfected whereby a contracting railroad company will be engaged on the Hetch Hetchy Railroad,

locomotives and rolling stock must be purchased at once, The cost for the railroad equipment to be purchased the first year will be $60,000, which expenditure will be saved if contract for the operation of the road is awarded.

The following is a list of the expenditures which are contemplated on the Hetch Hetchy project during 1917: The $4,000,000 requested to be appropriated for the Hetch Hetchy dam and the $6,000,000 required for the aqueduct from Early Intake to Moccasin Creek will not all be expended during the present year, but must be in the City Treasury before the contracts for the dam and aqueduct tunnel are awarded.

APPROPRIATIONS REQUESTED FOR HETCH HETCHY WATER SUPPLY, - - - -JANUARY, 1917.

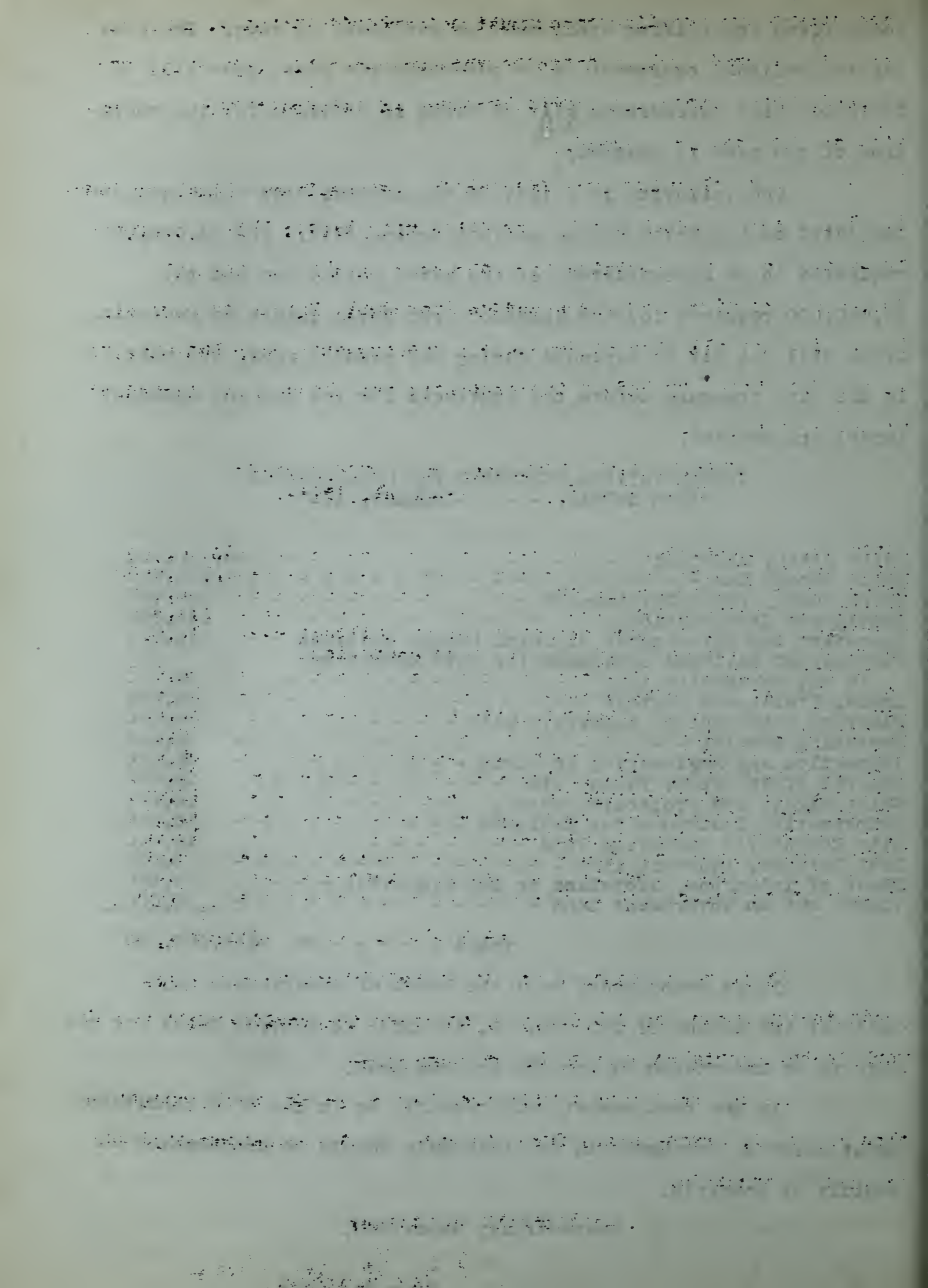
Hetch Hetchy Aqueduct -	6,000,000
Hetch Hetchy Dam -	4,000,000
Lower Cherry Power Development - - - - - - - - - - - - - -	500,000
Contingent Construction - - - - - - - - - - - - - - - - - -	115,500
Operation and Maintenance of Hetch Hetchy Railroad - -	110,000
Purchase of Railroad Equipment (in case operation is not contracted for) - - - - - - - - - - - - - - - - -	60,000
Roads, Trails and Surveys - - - - - - - - - - - - - - - - -	55,000
Clearing Hetch Hetchy Reservoir Site - - - - - - - - - -	30,000
Operating Sawmill -	30,000
Inspection and Engineering in Field - - - - - - - - - - -	30,000
General Office Work, Plans, etc. - - - - - - - - - - - -	25,000
Water Rights and Protective Work - - - - - - - - - - - -	12,000
Compensation Insurance for Employes - - - - - - - - - -	10,000
City Engineer's Revolving Fund - - - - - - - - - - - - -	10,000
Test Borings, Aqueduct Line - - - - - - - - - - - - - - -	6,000
Lease of Telephone, Groveland to San Francisco - - - - -	4,500
Timber cut on Government Land - - - - - - - - - - - - - -	2,000
Total - - - - - - - -	$11,000,000

It is recommended that the Board of Supervisors sell bonds to the amount of $11,000,000, in order to provide funds for the work to be undertaken during the present year.

As the bond market will probably be in the best condition about March 1, arrangements for this sale should be consummated as rapidly as possible.

Respectfully submitted,

City Engineer.



APPENDIX I

CONTRACTS OPERATIVE DURING 1916.

Contract #4. "For Clearing Portion of Hetch Hetchy Reservoir Site", was awarded on October 1, 1915, to A.J. Reeder. Owing to the heavy snowfall in February, an extension of 90 days after March 16, 1916, was given the Contractor.

On August 28, final payment of $6250. was recommended. The total amount paid the Contractor under this contract was $30,050.80.

Contract #5. "For Furnishing Air Compressing Plant and Drills", was awarded on September 15, 1915. Final Payment on all propositions was recommended on February 21, 1916. The total amount paid the Contractors was $10,327.50.

The machinery furnished under this contract was all assembled and erected at Hetch Hetchy dam site. It has proven very satisfactory and has been used in completion of diversion tunnel, road and trail work and various grading operations in the vicinity of Hetch Hetchy Camp. The Compressor will furnish air for drills and other machinery during the whole period of construction of the dam.

Contract #6. "For Furnishing Hoisting Engine and Boiler", was awarded on October 11, 1915, to A.L. Young Machinery Company. The engine originally furnished under the contract proved defective and has been replaced by the Contractor. Final payment is about to be recommended. The total amount paid the Contractor under this contract will be $1375.

Contract #7, "For the Construction of the Hetch Hetchy Railroad", was awarded on December 6, 1915, to F. Rolandi for the estimated sum of $1,543,080.74. At that time there was not sufficient money available for the award to be made, but on February 15, 1916, the Auditor certified the contract. Actual construction was begun on February 11, 1916, and will be completed by May, 1917. The total

estimated value of the work completed December 31, 1916, was $1,152,127.50.

Contract #8, "For Furnishing Cement", was awarded on October 26, 1915, to Santa Cruz Portland Cement Company at a cost of $2.67 per bbl., f.o.b. Chinese. During 1915, 2350 barrels were delivered at Chinese before December, at which time the snowfall effectively stopped hauling so that delivery was not resumed until May, 1916.

Owing to the long haul, it was found necessary to double sack the cement, which was done at an increased price of 11¼ cents per sack, less 10 cents for each sack returned in good condition to the Company's factory.

Final payment was recommended on October 24, 1916.

The total amount of cement called for under the contract was furnished and delivered.

Contract #9, "For Hauling Cement from Chinese, a Station on the Sierra Railway of California, Tuolumne County, to Hetch Hetchy Dam Site", was awarded on November 6, 1915, to Charles B. Dunham, at $23. per ton. Final payment was recommended on October 31, 1916.

Contract #10, "For Drifting Tunnels, Lower Cherry Aqueduct"; Proposals were received August 9, 1916, and the contract was awarded August 11 to MacArthur Brothers Company for the estimated sum of $53,785.

The value of the work completed December 1, was $17,290.49. This work has proceeded slowly, due to conditions unforeseen by the Contractor and also to slow delivery of machinery.

Under date of December 14, an extension of 60 days was granted the Contractor from and after January 18, 1917, in which to complete his contract.

This contract is for drifting the 5 tunnels on the Lower Cherry aqueduct. The total length for the drifting of which, proposals were received was 4400 feet, but the City did a portion of

this before the Contractor was able to begin work, leaving a total amount to be drifted by the Contractor of 3950 feet.

Of this distance there have been completed 2206 feet, leaving a balance of 1744 feet yet to be done.

As these tunnels are to be permanent, it will be necessary to line portions of them where there is blocky caving rock with concrete.

Contract #11, "For Making Core Borings, Hetch Hetchy Aqueduct". Proposals were received July 26, 1916, and contract was awarded July 28, to International Diamond Drill Contracting Company, for the estimated sum of $24,923.29.

Work has proceeded in a very satisfactory manner and the contract is now completed, a total of $20,002.13 having been paid to the Contractor.

The core recovery on drill holes has been very high and the samples representing the material which will be encountered in tunnel construction are stored in the Groveland office.

The work as bid on was for drilling 10 holes along the Hetch Hetchy aqueduct from Early Intake to Priest Regulating Reservoir. The total length of holes included in the contract was 7584 feet. Owing to the relocation of a portion of the aqueduct line between South Fork of Tuolumne River and Priest Reservoir, this quantity has been cut to 5949 feet. The borings show very good material through which the tunnel aqueduct will be drifted.

Contract #12, "For furnishing and delivering Hydraulic Machinery and Equipment, Lower Cherry River Power Development". Proposals were received August 9, 1916, and the contract awarded August 16, 1916, to the Pelton Water Wheel Company in the sum of $18,814. Under date of December 26, 1916, the first progress payment was recommended in the sum of $9407.

The machinery to be furnished under this contract was completed on December 1, and was shipped to Chinese, from which point it will be hauled to Early Intake as soon as the roads permit.

The machinery covered by this contract includes three 1500 h.p. Francis turbines, complete with governors, relief valves, and gate valves, together with all accessories.

Contract #13, "For Furnishing and Delivering Electric Generators and Exciters, Lower Cherry River Power Development", Bids were received August 9, 1916, and the contract awarded August 16, to the General Electric Company in the sum of $14,321.

The first unit will be delivered March 29, 1917, and the complete delivery made April 18, 1917.

The machinery to be furnished under this contract consists of three 1000 K.V.A. generators, with direct connected exciters, and one motor generator exciter.

Contract #14, "For Furnishing and Delivering Electric Switchboards and Equipment, Lower Cherry River Power Development", Bids were received September 13, 1916, and the contract awarded September 20, 1916, to the General Electric Company in the sum of $2,849.50. Delivery of the switchboard equipment will be made March 16, 1917.

This contract covers the furnishing of the complete switchboard, with all necessary instruments and switches for the three generators and exciters to be furnished under Contract #13.

Contract #15, "For Furnishing and Delivering Electric Transformers, Lower Cherry River Power Development". Bids were received September 6, 1916, and the contract awarded September 8, 1916, to the Westinghouse Electric Manufacturing Company in the sum of $7700. Delivery of the transformers will be made March 29, 1917.

This contract covers the furnishing and delivering of four 1000 K.V.A. oil insulated, water cooled, outdoor type, electric transformers and an oil filter.

Contract #16, "For Furnishing and Delivering Cedar Line Poles, Lower Cherry River Power Development". Bids were received September 20, 1916, and all bids were rejected as it was possible to secure usable poles locally at a lower cost than the prices bid.

Contract #17, "For Furnishing and Installing Riveted Steel Pressure Pipe Line, Lower Cherry River Power Development". Bids were received October 20, 1916, and the contract awarded October 27, 1916, to the Western Pipe & Steel Company, in the sum of $7558.

This pipe is being manufactured and will later be shipped to Rosasco, from which point it will be hauled to the power house site at Early Intake as soon as the roads will permit. It will thereafter be installed as soon as the excavation at the power house site and intake has been completed.

Contract #18, "For Furnishing and Delivering Bare Copper Wire, Lower Cherry River Power Development". Bids were received October 18, 1916, and the contract awarded to John A. Roebling's Sons Company, on November 10, 1916, in the estimated sum of $20,172.70.

Since the contract was awarded, advantage has been taken of a provision in the contract, and the quantity increased by 25%, raising the contract price to a total of $25,215.88.

Delivery of this material will be made April 1, 1917.

The quantity of wire to be furnished under this contract is sufficient for the construction of 38 miles of 3-phase transmission lines and branches.

Contract #19, "For Furnishing Logging Road Engine". Bids were received October 18, 1916, and contract awarded October 20, to Leland Equipment Company, for the sum of $2490.

Under date of December 27, a first payment was recommended in the amount of $1867.50.

The engine purchased under this contract is a duplicate of

the one purchased in 1915 under Contract #3, which has proved very satisfactory.

It is to be used for logging from the lands adjacent to Canyon Ranch Sawmill and when this work is completed, will be used in the construction of the Hetch Hetchy Dam.

Contract #20, "For Furnishing and Delivering Insulators, Crossarms and Pins, Lower Cherry River Power Development". Bids were received December 1, but as there were no bids covering all of the material, proposals were again invited and received December 11, 1916, and the contract awarded to Pierson, Roeding Co.; on December 13, 1916, in the sum of $2956. The contract provides for the delivery of the material by April 1, 1917.

Contract #21, "For Making Core Borings at Hetch Hetchy Dam Site". Bids were advertised to be received by the Board of Public Works on December 27, 1916, but no bids were submitted. This work was readvertised, proposals received January 5, 1917, and the contract awarded to the International Diamond Drill Contracting Company at an estimated price of $14,675. This contract will include about 1900 feet of borings at the Hetch Hetchy damsite and will determine the character of the formation, both below the riverbed and up on the slopes.

Contract #22, "For Furnishing and Erecting Sheet Metal Work for the Power Station, Lower Cherry River Power Development". Bids were received December 20, 1916, and the contract awarded December 22, 1916, to the Asbestos Protected Metal Company in the sum of $2150. The contract provides for the completion of this work by February 26, 1917, or 10 days after the completion of the building framework. The contract includes, besides the covering of the power house building proper, the sheet metal work for a small oil house.

STATEMENT OF GENERAL FUND EXPENDITURES FOR WATER SUPPLY PURPOSES - FROM 1900 to 1910.

December 30, 1916.

		Amount Expended
Expended before fire of 1906 - Engineers, etc.,		$ 43,999.39
Expenses of Marsden Manson on trips to Washington		670.49
Printing reports of City Engineer		2,117.50
Expenses delegations to Washington		3,345.78
Experts' fees and expenses:		
Desmond Fitzgerald - fee	$1,000.00	
" expenses	347.24	1,347.24
C.D. Marx - fee	$1,000.00	
" expenses	19.75	1,019.75
Expenses Supervisors to Hetch Hetchy		2,145.85
Purchase of lands:		
Bergen Right of Way	$ 548.00	
Elmer E. Smith purchase	50,800.00	51,348.00
Maps, Blueprints and Photographs		965.45
Supplies and Transportation		1,725.78
Wages, Salaries, etc., Engineers & Assistants		6,279.70
Legal expenses - G.W. Woodruff		445.00
Marsden Manson, City Engineer - Expenses		2,810.00
Total expended		$118,219.93

STATEMENT OF WATER SUPPLY BOND FUND OF 1909

December 30, 1916.

		Amount Expended
Experts' fees and expenses		$ 7,065.15
Legal Expenses by City Attorney:-		
Land Appraisement	$ 2,000.00	
Miscellaneous	10,100.48	
Dillon & Hubbard	2,000.00	
Legal Expenses, Board of Public Works	200.00	14,300.48
Photograph Supplies		96.30
Instruments		837.91
Maps and Blueprints		529.48
Supplies and Transportation		7,705.46
Wages Engineers and Assistants		17,411.50
Marsden Manson, City Engineer, for Hetch Hetchy Expenses 1910-1911		13,000.00
Purchase of Lands, Interest, etc,:-		
Elmer E. Smith	$105,884.60	
Lizzie B. Covel	8,289.60	
" " "	8,789.60	
Tuolumne Water Supply Co.	400,000.00	
To M. Manson for timber at Lake Eleanor (to Govt,)	13,128.77	
For fencing Hog Ranch and Middle Fork Homestead tract at Eleanor	1,000.00	537,092.57
Bond Circulars, Stamps, Telegrams, etc,		210.80
Expenses to Washington of P.H. McCarthy, P.V.Long, &c-		2,699.50
Expenses of Supervisors to Hetch Hetchy		2,265.91
Total expended		$603,215.06

STATEMENT OF 1910 WATER CONSTRUCTION BOND FUND

December 30, 1916.

S U M M A R Y

Total bonds sold		$4,185,000.00
Premiums		200.00
Sundry credits from Freeman reports, etc.		1,428.91
Total amount available from bonds, etc. Dec. 30, 1916		$4,186,628.91
Total appropriations	$3,006,388.45	
Probable balances from appropriations to be returned to fund	31,880.44	
Net total appropriations	$2,974,508.01	
Amount expended direct from fund, without appropriation	851,954.97	
Net total appropriations and expended without appropriations		3,826,462.98
Net amount available for further appropriations December 30, 1916		$360,165.93

Summary of actual cash expenditures to date on the Hetch Hetchy Water Supply from all sources (includes amounts actually paid only - no liabilities):-

General Fund 1900 to 1910	$ 118,219.93
1909 Water Supply Bond Fund	603,215.06
1910 Water Construction Bond Fund	2,876,970.68
Total	$3,598,405.67

Note: Above as shown by books of Board of Supervisors.

STATEMENT OF 1910 WATER CONSTRUCTION BOND FUND

December 30, 1916.

(Taken from Books of Board of Supervisors)

	Appropriation	Expended	Balance	Deficit
Priest Hill Road Construction	2,500.00	2,500.00		
Investigating Sources of Water Supply B.P.W.	75,659.31	85,293.50		9,634.19
Lake Eleanor	57,500.00	25,626.32	31,873.68	
Investigating McCloud River Project	500.00	500.00		
Engineer's Appraisal of Spring Valley Water System	3,500.00	4,313.20		813.20
Investigating claims of Spring Valley Water Co. in Alameda Co.	1,400.00	1,692.20		292.20
Hog Ranch Road to Hetch Hetchy Dam Site	180,943.84	180,943.84		
3- Hydro-Electric Experts	5,000.00	5,000.00		
Co-operative Road Work	3,500.00	3,500.00		
Investigation of Turlock & Modesto Irrigation Dist. by City Engineer	500.00	2,204.80		1,704.80
City Engineer's Expenses, to be accounted for - (old account) ($150.25 deducted from each side;all but $370.59 already accounted for)	10,000.00	10,000.00		
Installing Sawmill	13,000.00	13,000.24		.24
Telephone Lines	5,000.00	4,993.24	6.76	
Investigation of Hetch Hetchy by City Engineer (Expenses)	2,000.00	2,000.00		

HETCH HETCHY STATEMENT (continued)

	Appropriation	Expended	Balance	Deficit
Surveys Railroad Location	8,000.00	7,931.06	68.94	
Drilling Wells & Boring Test Holes in Richmond & Sunset Districts	21,134.06	19,906.44	1,227.62	
Hydrography, B.P.W. & Government	25,000.00	17,070,69	7,929.31	
Roads, Trails, Surveys, etc.	110,250.00	97,491.67	12,758.33	
Purchase of Gauging Apparatus & Instruments	5,000.00	3,212,61	1,787.39	
Water Rights & Protective Work	52,000.00	33,053.81	18,946.19	
General Office Work, Plans, etc. (including Geology, Engineering, etc.)	106,000.00	50,927.88	55,072.12	
Inspection & Engineering in Field	51,000.00	45,828.25	5,171.75	
Permanent Camps & Equipment	44,500.00	31,057.76	13,442.24	
Surveys Aqueduct Location	27,100.00	22,468.63	4,631.37	
Test Borings, H.H. Aqueduct	25,000.00	10,484.38	14,515.62	
Operating Sawmill	40,000.00	32,766.39	7,233.61	
Clearing Reservoir	51,000.00	49,334.97	1,665.03	
Hetch Hetchy Dam & Appurtenances (Diversion Dam & Tunnel, Foundation Work for Main H.H. Dam)	165,500.00	128,586.52	36,913.48	
Insurance with State Compensation Inc. Fund	6,444.73	6,444.73		
Lower Cherry Power Development	100,000.00	52,352.64	47,647.36	
City Engineer's Part Salary	5,000.00	2,500.20	2,499.80	

	Appropriation	Expended	Balance	Deficit
Inspecting Track Material, Bridge Material, etc.	1,100.00	754.91	345.09	
U.S. Claims for Timber (Timber cut on Govt. Land)	2,000.00	1,549.08	450.92	
Railroad from Rosasco to H.H. Dam Site	1,543,080.74	824,374.14	718,706.60	
Electric Generators, Cherry Creek	14,321.00		14,321.00	
Hydraulic Machinery, Cherry Creek	19,804.00	9,407.00	10,397.00	
Electric Transformers, Cherry Creek	7,700.00		7,700.00	
Electric Switchboards, Cherry Creek	2,849.50		2,849.50	
Steel Pipe, Cherry Creek	7,558.00		7,558.00	
Copper Wire, Cherry Creek	25,543.18		25,543.18	
Insulators & Cross Arms, Cherry Creek	3,200.00		3,200.00	
Sheet Metal Work, Cherry Creek	2,150.00		2,150.00	
Claims for Destruction of Grazing	1,603.01		1,603.01	
Totals for pages 35,36,37 (for Board of Public Works)	$2,834,841.37	$1,789,071.10	$1,058,214.90	$12,444.63

HETCH HETCHY STATEMENT (Continued)

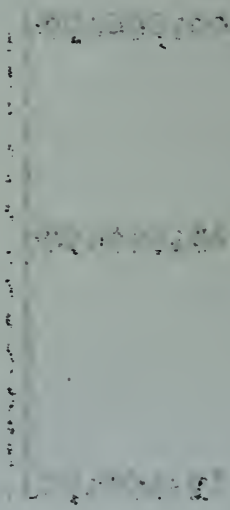
	Appropriation	Expended	Balance	Deficit
City Attorney's Legal Expenses (olddaccount)	39,000.00	42,259.19		3,259.19
San Miguel Reservoir Site		423.70		423.70
Cherry Creek Reservoir, Annual Charge for Government Rights, (old account)	1,890.00	2,835.00		945.00
Investigation of Water Supply, U.S. Government Engineers, etc.	21,250.00	191,600.22		170,350.22
Auto for J.J. Phillips	600.00	600.00		
Investigation of Hetch Hetchy by City Attorney	2,000.00	2,000.00		
Printing Bond Registers	1,248.75	1,248.75		
Legal Expenses, City Attorney's Office	3,450.00	3,323.75	126.25	
Investigation by City Attorney of Poopenaut Valley Reservoir Site	1,500.00	388.88	1,111.12	
Investigation of Hetch Hetchy,- Tuolumne District, City Atty	36,933.55	30,999.68	5,933.87	
Cherry Creek Reservoir, Annual Charge for Government Rights (new account)	1,890.00	1,890.00		
Taxes in Tuolumne County	8,983.23	8,983.23		
Rights of Way - by City Attorney	20,000.00	15,718.65	4,281.35	

HETCH HETCHY STATEMENT (continued)

	Appropriation	Expended	Balance	Deficit
Purchase of Lands, by City Attorney	25,800.00	25,800.00		
Legal expenses at Washington, City Attorney	7,001.55	7,001.55		
Miscellaneous Expenditures by Board of Supervisors		10,847.23		10,847.23
Totals of pages 38 and 39, for City Attorney, Supervisors, etc.	$171,547.08	$345,919.83	$11,452.59	$185,825.34

HETCH HETCHY STATEMENT (Continued)

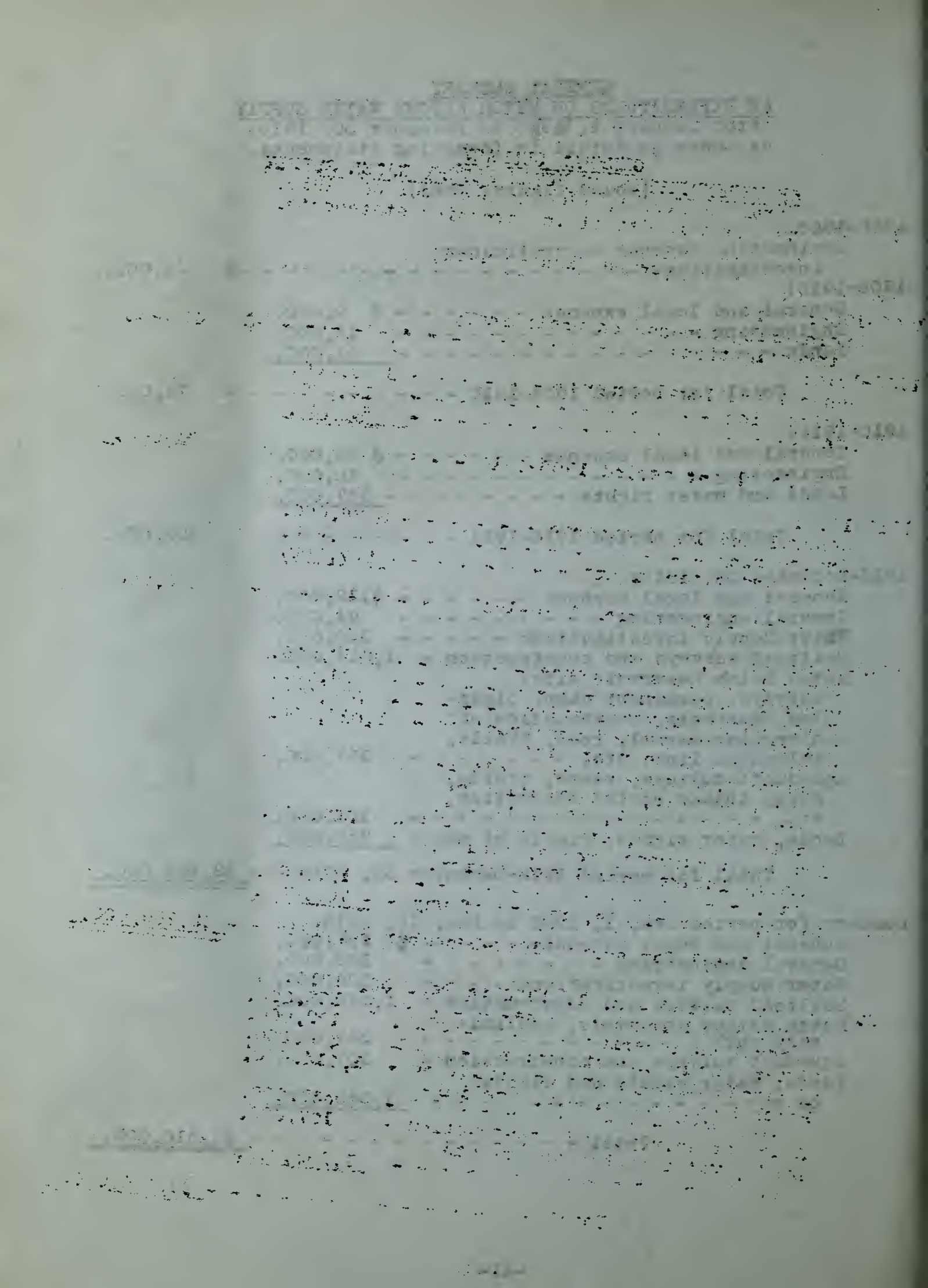
	Appropriation	Expended	Balance	Deficit
Lands - Purchase of Tuolumne Water Supply Co. lands, properties, rights, etc.		600,000.00		
Interest on $600,000 from date of option to date of purchase		36,000.00		652,000.00
Moneys expended in protection and development of said lands, properties and rights		16,000.00		
Lands - Purchase of certain lots in Tuolumne Co. from James Samuel Burch		1,675.00		1,675.00
Lands - J.F. [illegible] English for Sonoma Abstract & Trust Co., abstract of title on Burch lands		10.00		10.00
Total for Page		653,685.00		653,685.00
Totals for pages 35,36 & 37 Bd. Pub. Wks.	2,834,841.37	1,789,071.10	1,058,214.90	12,444.63
Totals for pages 38 & 39, City Atty, B/S etc.	171,547.08	345,919.83	11,452.59	185,825.34
Grand totals of all pages for entire Bond Fund	$3,006,388.45	$2,788,675.93	$1,069,667.49	$851,954.97



GENERAL SUMMARY
OF EXPENDITURES ON HETCH HETCHY WATER SUPPLY
from January 1, 1900 to December 30, 1916,
as shown in detail in foregoing statements.

(round figures used)

1900-1906:		
Engineering expense on preliminary investigations		$ 44,000.
1906-1910:		
General and legal expense	$ 9,000.	
Engineering	14,000.	
Lands	51,000.	
Total for period 1906-1910		74,000.
1910-1911:		
General and legal expense	$ 26,000.	
Engineering	40,000.	
Lands and water rights	537,000.	
Total for period 1910-1911		603,000.
1912-December 30, 1916:		
General and legal expense	$132,000.	
General engineering	94,000.	
Water Supply investigations	320,000.	
Railroad surveys and construction	1,014,000.	
Hetch Hetch Reservoir site: surveys, permanent camp, clearing reservoir, construction of diversion tunnel, road, trails, telephone line, etc.	357,000.	
Aqueduct: surveys, roads, trails, Early Intake portal excavation, etc.	107,000.	
Lands, water rights, rights of way	765,000.	
Total for period 1912-December 30, 1916		$2,789,000.
Summary for period Jan. 1, 1900 to Dec. 30, 1916:		
General and legal expense	$ 167,000.	
General engineering	192,000.	
Water Supply investigations	320,000.	
Railroad Surveys and construction	1,014,000.	
Hetch Hetchy Reservoir, preliminary work	357,000.	
Aqueduct surveys and construction	107,000.	
Lands, water rights and rights of way	1,353,000.	
Total		$3,510,000.



I N D E X

The Hetch Hetchy Project

of the

City and County of San Francisco
California

Its Progress, Prospects and Possibilities

By

M. M. O'SHAUGHNESSY
City Engineer

JANUARY, 1920

Issued by the City and County of San Francisco

FOREWORD

The termination of the Great War has turned the minds of the American people to the problems of reconstruction, and capital, labor and the industries are now being directed to the channels of peace. In his address to Congress on December 2, 1918, President Wilson said: "It seems to me important, therefore, that the development of public works of every sort should be promptly resumed, in order that opportunities should be created for unskilled labor in particular." The City and County of San Francisco therefore deems it opportune to direct briefly the attention of those interested in municipal undertakings to the progress, prospects and possibilities of the Hetch Hetchy Water Supply and Power Project. In the recent war crisis the bonds of this project received the approval of the War Industries and Capital Issues Board of the Federal Government.

For the purpose of enlightening the public generally, and especially those who follow the markets for municipal securities, as well as for the purpose of announcing resumption on a large scale of work on this great public enterprise, the following outline of the accomplishments and intentions of the City in respect to the Hetch Hetchy project is respectfully submitted.

M. M. O'SHAUGHNESSY,
City Engineer.

San Francisco, California,
January, 1920.

The Hetch Hetchy Project in a Nutshell:

The Hetch Hetchy projeet is a plan for a munieipal water supply, evolved by thc City and County of San Franeiseo, after a thorough and eomprehensive stndy of all possible sources, for thc eolleetion and storage of waters of the Tuolumne River and its tributaries near their sourees in the Sierra Nevada Mountains, and the transmission of those waters across the San Joaquin Valley and through the Coast Range of mountains for delivery to the City of San Franeiseo and its environs; due advantage being taken of appropriate drops in the conduit routes for the generation of the maximum quantity of hydro-electrie power which ean thereby be eeonomically developed.

History:

The projeet had its beginnings back in 1901, when James D. Phelan, then Mayor of the City, now United States Senator from California, filed water locations on the Tuolumne River and its tributaries, the Cherry River and Eleanor Creek. These appropriations were kept alive by preliminary development work until a permit could be obtained from the Federal Government for the aequisition of storage reservoir sites situated on public lands within the limits of the Yosemite National Park (not Yosemite Valley). This permit was granted by Seeretary of the Interior Garfield in 1908 to lands and waters tributary to the Tuolumne River in the northern part of the Park and twenty miles distant from the Yosemite Valley proper, which is drained by the Mereed River. Having aequired this permit, San Francisco proceeded to aequire, at an expense of $1,915,000, all privately owned lands in the Hetch Hetehy Valley and the rights and holdings of William Ham Hall, John Hays Hammond and others on the Tuolumne and Cherry Rivers and on Eleanor Creek, a tributary of the Cherry, rising at the outlet of Lake Eleanor. With the aceession of the Ballinger administration in the Interior Department, a movement was started by eertain eoteries of so-called "nature-lovers" and others to revoke that portion of the Garfield permit relating to the Hetch Hetchy Valley, which is the largest of the proposed reservoir sites. Seeretary Ballinger went out of offiee after issuing an order directing San Franciseo to show cause against this revoeation. President Taft ordered an investigation and report by a Board of United States Army Engineers,

consisting of Colonel John Biddle, Lieutenant Colonel Harry Taylor and Major Spencer Cosby. This Board of Engineers examined exhaustively all alternative sources of supply which had been suggested as available for San Francisco's use, including the Stanislaus, Calaveras, Mokelumne, Cosumnes, American, Yuba, Feather, McCloud, Sacramento, Eel, and San Joaquin Rivers, and the local sources of the Spring Valley Water Company. The Army Engineers' report, made to Secretary Fisher, Mr. Ballinger's successor, under date of February 19, 1913, recommended the use of the Hetch Hetchy Valley and the Tuolumne supply as being the cheapest and most economical for the City's use and affording the greatest hydro-electric development possibilities. Previous to the report of this Army Board, the City had an exhaustive examination of all available sources made by John R. Freeman, an engineer of national repute, associated with the water supplies of Boston and New York. He strongly recommended the Tuolumne source as the best and outlined the scheme of development which, with some necessary modifications, is now being followed.

After taking testimony and examining all reports submitted, Secretary Fisher gave it as his opinion that Congress alone had the power to grant the privileges sought by the City. After a great deal of argument before Congress, the "Raker Bill" was passed by both Houses and signed by the President on December 19, 1913. This act was framed on the recommendation of Secretary Lane of the Interior Department and Secretary Houston of the Department of Agriculture, and by it Congress (Stats. 1913, p. 242) vested forever the City's rights in 420,000 acres of the public domain.

The water locations have from their inception been carefully protected and title to the same is fully vested in San Francisco under the provisions of the Civil Code of California. Antecedent to this, on January 4, 1910, the people of San Francisco, by a vote of 32,886 for and 1,609 against, authorized the issuance of $45,000,000 in bonds for the construction of the project.

Actual work was commenced as soon as the Congressional grant was obtained. Surveys were completed, many miles of wagon road were built, a broad-gauge railroad sixty-eight miles long was located and built, the floor of Hetch Hetchy Valley was cleared of timber, a sawmill was constructed and put in operation, diamond drill borings at the main damsite and along the line of the tunnel aqueduct were

made, a construction power plant was built, with a dam at Lake Eleanor to store eight billion gallons to carry the plant through the dry season, and an aqueduct to supply the plant with water, electric transmission lines connect it with all working points on the tunnel aqueduct, camps, warehouses, headquarters buildings were constructed, and work was finally begun on the Hetch Hetchy dam foundations and diversion tunnel and at all tunnel portals and shafts on the Mountain Division of the aqueduct. These accomplishments will be described in greater detail, but are enumerated here to emphasize that Hetch Hetchy was fast becoming a reality when the entry of the United States into the war against Germany necessitated a slowing down of operations.

During the period of the war the City carried on work with a force of from 400 to 500 men, with due care always not to interfere with the selective draft or the nation's need for materials and equipment. Progress was necessarily not as rapid as would otherwise have been the case, but it has sufficed to place the project in a position where the maximum force of men can now be advantageously employed to hurry the undertaking to completion. Sound economic reasoning dictates that the Mountain or power-generating division of the project be completed first, in order that the burden upon San Francisco's taxpayers of paying interest during construction may be reduced through receipts from power sales at the earliest possible moment. The dominant purpose of the project is, however, water supply, and every effort must be made to complete the water conduits without unnecessary delay in order to remedy the water shortage from which the San Francisco Bay cities have long been suffering.

Outline of the Principal Engineering Features:

The space afforded in this resumé suffices for only a brief description of the principal engineering features of the project. For convenience the work has been divided into ten divisions, to be known as the Lake Eleanor, Hetch Hetchy, Mountain, Priest, Moccasin, Foothill, San Joaquin, Coast Range, Bay Crossing and Peninsula Divisions. Outside of surveys, geological and engineering studies so far conducted over the entire work, the construction accomplished to date has been entirely on the Lake Eleanor, Hetch Hetchy and Mountain Divisions. The following structures have been completed or are under construction:

Hetch Hetchy Railroad:

The Hetch Hetchy Railroad, sixty-eight miles in length, extends eastward into the Sierras from Hetch Hetchy Junction. The elevation of Hetch Hetchy Junction is 935 feet, from which the railroad, after crossing two low ridges, drops to 625 feet in a distance of nine miles to cross the Tuolumne River, some twelve feet above extreme high water. From the Tuolumne River the road extends to Jacksonville, thence up Moccasin Creek and Grizzly Gulch to Priest, and thence to Big Oak Flat and Groveland. Most of the climb for eastward traffic toward the dam is on a grade from 3 to 4 per cent.

Due to the roughness of the country, and since the road is to be operated for project freight traffic chiefly, sharp curvature has been frequently used, the maximum being 30°, and curves of from 18° to 26° are numerous.

From Groveland the road continues east past Hamilton Station; thence it descends to the South and Middle Forks of the Tuolumne River, which are crossed on ballast deck trestles, and finally ascends the Poopenaut Pass where an elevation of 5,064 feet is attained; thence a continuous 4% grade descends to the damsite bench, 3,869 feet elevation. This latter stretch of the road, nine miles in length, was exceedingly rough construction, in many instances having been hewn out from almost vertical cliffs of solid granite, and was made twenty-two feet wide, making in future easy access to some of the most attractive scenery.

Over 1,000,000 cubic yards of excavation were necessary for the railroad. A large portion of this material was in granite rock, and over one-half million feet of lumber was used for trestling the various small canyons which the road crosses.

For all but the nine miles descending from the summit of the ridge at Hog Ranch into Hetch Hetchy Valley, the width of the roadbed is sixteen feet at subgrade.

Lake Eleanor Dam:

To insure a sufficient water supply for operating Early Intake Powerhouse through the dry season, and to secure its water rights under the laws of the State of California, a concrete dam has been erected by the City across a gorge one mile below Lake Eleanor, and raises the surface of the lake thirty-five feet, to 4,660 feet above the sea.

This structure is 1,260 feet in length, 70 feet in maximum

height, and contains 11,000 cubic yards of concrete, heavily reinforced. The dam is of the buttressed arch type, but with several original features for additional safety, developed by the City Engineer's studies. It has twenty arches, each with a span of forty feet. The arches are on an incline of 50° and are supported by buttresses, heavily reinforced. It is curved in plan and located at the site of and will form a part of a future larger dam. An interesting feature is that the cross-section of the arches is circular on a horizontal plane and elliptical on a normal plane.

Early Intake Construction Power Plant, Aqueduct and Transmission Line:

The temporary power plant is located on the Tuolumne River at Early Intake, about ten miles distant from Lake Eleanor. The available head is approximately 345.5 feet. The water for power purposes is diverted from the natural flow of Cherry River, augmented when necessary by water released from Lake Eleanor, and is then led through a conduit of 130 million gallons daily capacity and 3.3 miles long, consisting of 1.2 miles of open ditch, 1.1 miles of flume and one mile of tunnel.

The forebay at the head of the pipe line consists of an enlarged section of the flume and affords a limited capacity for regulating purposes. Owing to the steep hillsides, it was impractical to create a forebay reservoir. From this forebay the water is carried to the powerhouse in a forty-two inch riveted steel pipe 530 feet in length. The thickness of the pipe ranges from three-sixteenths inch at the top to three-eighths inch at the bottom. Some idea of the character of the country will be gained by realizing that this pipe line drops 320 feet in 530 feet, equivalent to seventy-five per cent grade. The powerhouse building, being intended for temporary purposes only, is of wood frame construction covered with asbestos-protected corrugated iron; the foundations, however, are of massive concrete necessary to resist the floods; the machinery and equipment are of the most modern type and design, and every precaution has been taken to secure reliability of service in connection with the plant. The power equipment installed in the powerhouse consists of three turbines of the Francis Pelton type, designed to operate at 720 revolutions per minute and to develop 1,500 horsepower each. Each of these water wheels is direct connected to a

2,300-volt, three-phase, sixty-cycle generator of 1,000 kilowatts capacity, with a direct-connected exciter operating at 125 volts. The main step-up transformers, four in number (including the spare transformer), are located in the powerhouse, in a space separated from the machine floor. They raise the voltage from 2,300 to 22,000 volts for transmission to the work. From the powerhouse power is transmitted for construction purposes over two lines, one extending eleven miles easterly to the Hetch Hetchy damsite, the other nineteen miles west along the line of the aqueduct to Priest. At each of the tunnel adits, and at the damsite, transformer substations reduce the voltage from 22,000 to 440 or 220 volts, as may be required for the motors. The construction of this plant is completed. Power generated in excess of the City's requirements is being sold. and during the fiscal year 1918-1919 yielded a revenue of $67,528.10.

Hetch Hetchy Dam and Reservoir:

At its lower end, Hetch Hetchy Valley narrows to a gorge about sixty feet wide at ordinary low water level (elevation 3,500 feet), and 900 feet wide at the elevation of the crest of the proposed ultimate dam (elevation 3,812 feet). The underlying bedrock has been very carefully studied by means of diamond drill borings. It will be necessary to excavate to an average depth of seventy-five feet below the river bed in loose gravel, sand and boulders to obtain an excellent bedrock foundation. This depth is not excessive and has been exceeded in many of the large concrete dams constructed in recent years.

The dam is to be of the arched gravity type and built of cyclopean concrete, which is concrete in which are imbedded large blocks of stone ranging in size from about one cubic foot to the largest that can be handled by the derricks. For a number of years to come, the City's needs will be amply served by a reservoir of lesser capacity than the complete development of the valley, and for this reason the dam will be built in two installments. Work is in progress on the construction of the first installment, under a contract with the Utah Construction Company, signed August 12, 1919. The estimated cost of construction at the contract prices is $5,447,792.50. The principal items of the contract are estimated as follows:

Excavation below stream level	77,000 cu. yds.
Excavation above stream level	60,500 cu. yds.
Cyclopean masonry	300,200 cu. yds.
Concrete not included in cyclopean masonry	69,500 cu. yds.

This initial dam will have a maximum height above foundations of about 300 feet. Its length on the crest will be about 600 feet, and its thickness on the crest 15 feet. The spillway lip will be at elevation 3,720, which is 220 feet above the natural water surface elevation in the river at the damsite during the season of low flow. The spillway is to be of the siphon type, discharging over the downstream face of the dam. The top of the dam is designed to serve as a roadway. The time allowed the contractor for building this structure expires January 28, 1922.

The present contract includes the complete foundation below stream level for the ultimate dam. At its base, this foundation will have a thickness (up and down stream) of over 300 feet. When it becomes necessary to add to the reservoir capacity developed by the initial dam, the dam will be brought up to its full ultimate size by adding a thickness of eighty feet on the downstream face of the initial dam and building up eighty-five feet higher. This will make available eighty feet additional depth of reservoir, making the lake 300 feet deep at the dam. The total height of the dam above the foundations will then be nearly 400 feet, making it higher than any dam now existing in the world. The crest length will be about 900 feet, and the thickness at the crest 25 feet. As in the lower dam, the crest will be utilized as a roadway. The spillway will be a channel around the top of the dam, with the spillway lip at elevation 3,800. The siphon spillway will, of course, be closed permanently on completion of the dam to its ultimate height.

The initial dam will contain about 370,000 cubic yards of concrete, and the ultimate dam about 625,000 cubic yards.

The reservoir created by the initial dam will have a capacity of 66,000,000,000 gallons, or 202,000 acre-feet, and on raising to the ultimate height the capacity will become 112,000,000,000 gallons, or 343,000 acre-feet. This is five times the capacity of the Crystal Springs reservoir of the Spring Valley Water Company.

The floor of Hetch Hetchy Valley has been cleared of timber, in order to protect the impounded waters from contamination due to the decay of submerged timber. A diver-

sion tunnel twenty-four feet in diameter and 900 feet long has been driven through the rock promontory on the south side of the damsite. The waters of the Tuolumne River will be turned through this tunnel during the construction of the dam, and afterwards the tunnel will be utilized for the release of water from the reservoir. For the latter purpose there will also be a number of channels through the body of the dam, with an elaborate system of valves.

To provide lumber for the Hetch Hetchy development work, San Francisco is now operating a sawmill on its own land at Mather, adjacent to the railroad and nine miles from Hetch Hetchy damsite. This mill turns out 20,000 board feet of lumber daily. This lumber is now delivered to the various points along the Mountain Division of the aqueduct, where needed, at a cost of about $13 per thousand.

Mountain Aqueduct Twenty Miles Long:

From Hetch Hetchy reservoir to Early Intake, a distance of twelve miles, the river bed of the Tuolumne will serve as a conduit for the waters released from the Hetch Hetchy reservoir, until such time as the necessity for the generation of additional power will justify the construction of a tunnel from Hetch Hetchy damsite to the forebay above Early Intake.

From Early Intake the first section of the tunnel aqueduct extends to the South Fork of the Tuolumne, a distance of four and one-half miles. This tunnel can be worked from the two portals only, since the height of the mountain penetrated by the bore is too great to permit of any shafts being sunk to the tunnel line at intermediate points.

Work is now in progress at both portals. The rock encountered is extremely hard, requiring about thirty pounds of dynamite per lineal foot. The present rate of progress is about seven feet daily from each portal, but this can be more than doubled when additional shifts of labor are put to work and sufficient money is made available to the City Engineer to rush the construction, so that the tunnel can be completed in less than three years.

The time of completion of this tunnel is the controlling factor in the time necessary to supply San Francisco with 66,000 horsepower of electrical energy, as the remaining thirteen and one-half miles of tunnel between South Fork and the regulating reservoir above Moccasin Creek Power-

house can be worked from two portals, two intermediate shafts and seven adits.

Work on this section of the tunnel from South Fork to Priest regulating reservoir is now being advanced from Priest Portal and in both directions from the bottom of Big Creek shaft.

At Big Creek the tunnel grade is 575 feet below the ground surface, and the shaft is carried down 71 feet lower, making the total depth 646 feet. The cars bringing the broken rock from the heading dump into a rock pocket, from which the skips in the shafts are loaded by gravity, hence the need for the extra depth.

The second shaft, located near Second Garrotte, is not yet completed. On December 31, 1919, its depth was 320 feet. The work here is retarded by the presence of considerable quantities of water in the formation. The shaft will be about 800 feet deep when completed.

The status of the tunnel excavation on December 31, 1919, was as follows:

Heading.	Distance Excavated from Portal or Shaft.
Early Intake	3,008 feet
South Fork east	2,882 "
Big Creek east	327 "
Big Creek west	346 "
Priest	4,183 "
Total	10,746 feet

The tunnels will be ten feet three inches high and ten feet three inches wide inside the concrete lining of six inches minimum thickness. The aqueduct will have a discharge capacity of over 400,000,000 gallons daily.

Forces Engaged on Construction Work:

The work now being carried on in the field by the city's forces comprises the excavation of the aqueduct tunnels above described and the operation and maintenance of the Hetch Hetchy Railroad, the construction power system and the sawmill. The force engaged on all of this work averages about 500 men. The contractor constructing the Hetch Hetchy dam is employing on his preliminary work 300 men, making a total of about 800 men working on the project.

Future Stages of Project Construction:

Another tunnel 5.75 miles in length will extend from Moccasin Creek to Red Mountain Bar, where the Main Tuolumne River will be crossed with a short steel pipe. Thence a tunnel 11.3 miles in length will lead to Oakdale Portal, on the easterly side of the San Joaquin Valley.

From Oakdale Portal (about four miles southeasterly from the town of Knights Ferry), the commencement of the present survey, to Tesla Portal on the west side of the San Joaquin River (about eight miles southerly from Tracy), the aqueduct will consist of 45.2 miles of steel pressure pipes. The thickness of the steel pipe, and hence the cost, is practically proportional to the size and the water pressure, therefore the pipe line was located on the highest ground immediately adjacent to the direct or shortest line to be followed. The deciding factor on the size of the first installation will depend on the wishes and decisions of the transbay population of Alameda, Oakland, Berkeley, Richmond and adjacent communities, with about 400,000 population and $250,000,000 assessed valuation.

The aqueduct will be carried across the San Joaquin Valley in pressure pipe, which will pass under the San Joaquin River as a submerged pipe line, and the lower areas adjacent to the San Joaquin, subject to overflow during the annual floods, will probably be traversed by means of pipe lines on substantial reinforced concrete trestles.

Through the Coast Range from Tesla Portal to Irvington Gate House, except for a small steel siphon crossing the Alameda Creek channel, the aqueduct will consist of tunnels aggregating approximately thirty-one miles in length. This section has been the subject of close geological study and the surveyed location made follows what is at present considered the most feasible route avoiding fault lines and rock of uncertain character.

From Irvington Gate House westerly, the aqueduct will again consist of steel pressure pipe 19.1 miles in length, following practically a straight line from the Gate House to Dumbarton Straits, where the Bay crossing will be made by means of pipes placed either in the Bay bottom or in a subsurface concrete tube.

The line thence parallels the Southern Pacific Railroad, through the southerly portion of Redwood City to what is known as the Redwood Portal, two miles westerly from the

town of Redwood. From here the aqueduct will consist of tunnels, extending about one and one-half miles westward from the Redwood Portal to the main ridge between San Francisco Bay and Crystal Springs and San Andreas Lakes of the Spring Valley Water Company.

From this point the tunnels will follow beneath this main ridge to a point about one mile southwesterly from Baden Station. Here again the construction will be a short steel siphon, across the low area lying between the main Coast Range and San Bruno Mountain, to the San Bruno tunnel portal, crossing the southeast corner of Holy Cross Cemetery and about 500 feet east of the Boulevard. From the San Bruno portal to a city reservoir will be in tunnel.

The city has already acquired a large part of the site for the large terminal reservoir, known as the Amazon reservoir. It is located adjacent to the Crocker-Amazon tract, in the southerly part of the city, at an elevation of 240 feet, and will be designed to hold 300,000,000 gallons of water.

The location of the route has been made in the light of careful engineering studies, the controlling consideration being the permanence of the proposed structures, and the safety of the same, commensurate with reasonable economy.

With the source of water supply over 150 miles from the City, great care must be exercised to guard the aqueduct against possible interruption of service, due to any contingency whatsoever. Tunnels lined with concrete, intelligently located and properly built, will last for all time. Moreover, the expense of construction, in comparison with high pressure pipe of large diameter, is not excessive, when the cost of wide right of way for the latter is considered. Based on a comprehensive geological study of all practical routes, tunnels have been located in stable rock formation, as far as possible, free from the menace of earthquake faults. All portions of the line have been checked by means of triangulation, with U. S. Geological Survey bench marks, and all property lines traversed by the route have been measured and the records of ownership, etc., have been compared with County records, so that the necessary data is at hand for the acquisition of the right of way.

Power Development for Industrial Purposes:

The work above outlined is primarily to bring to San Francisco and the Bay communities 400,000,000 gallons of

pure mountain water daily. A very important feature of the project, however, is that besides supplying water for domestic purposes, the Mountain Division of the Hetch Hetchy project will render available immediately on its completion 66,000 horsepower of electrical energy, or 380,000,000 K. W.-hours annually. This will all be generated at the Moccasin Creek powerhouse, the first large unit on the line of the aqueduct.

When it is considered that at present there is consumed in San Francisco annually only 360,000,000 K. W.-hours, the tremendous value of the Hetch Hetchy Grant, from a power standpoint, can be more fully appreciated.

The electricity now consumed in this City is divided as follows:

Street railway system	63.6 %
Street lighting	2.23
Commercial lighting	9.42
Commercial power	21.2
Miscellaneous	3.55

By the completion of Moccasin Creek Powerhouse, the electrical energy available for San Francisco will be more than doubled. This will be of incalculable value in aiding the industrial development of this City and the Bay communities, which are now seriously hampered in their growth by lack of water and inadequate supply of power. Shipbuilding and manufactories of every description will be greatly stimulated, and the City's tangible assets tremendously increased.

Future Power Units:

An output exceeding 250,000 horsepower will ultimately be developed on the Hetch Hetchy project by dropping the water from the higher levels 8,000 to 10,000 feet altitude to the domestic supply terminal at Priest's, 900 feet above the sea level, as the City controls a watershed for its exclusive use of 416,640 acres, with an average runoff of two and one-half feet per year, which yields 1,041,600 acre-feet annually.

LEGAL STATUS OF HETCH HETCHY PROJECT

Water Rights:

It may be observed from a reading of the history of the efforts made by the City of San Francisco to secure its Tuolumne water supply that nothing has been left undone to protect the security of the City's water rights from a

legal standpoint. Not only do its water locations antedate practically all others on the Tuolumne River, but they have been kept valid by development work continuously performed, by the authorization of construction bonds as provided in Section 1416, Civil Code of California, and by the diligent prosecution of the City's applications for rights of way before the Interior Department and before Congress as prescribed in Section 1422, Civil Code.

The only appropriators diverting any quantity of water from the Tuolumne are the Modesto-Turlock Irrigation Districts and the La Grange Power Company, the extent of whose priorities has been carefully determined by the City's engineering advisers in estimating the quantity of water available for the City's use. Their conclusion, based on hydrographic studies extending over many years, is that with the storage proposed, enough water can be obtained from Tuolumne sources to satisfy these priorities and permit the City to divert an ultimate maximum of four hundred million gallons daily.

In paragraph (B), Section 9, of the Hetch Hetchy Grant from Congress the Irrigation Districts are restricted to the present Turlock and Modesto Districts of 250,000 acres, and their enlargement in the future to 300,000 acres. In paragraph 34, U. S. Army Engineers' report, Washington, February 19, 1913, opinion is rendered that there is adequate water for San Francisco, 400 million gallons daily and for 400,000 acres irrigated with 750,000 acre-feet storage. With a restriction to 300,000 acres in the Congressional Bill, San Francisco's portion is assured.

Rights of Way:

The Hetch Hetchy Grant from Congress and the various departmental approvals which have been given from time to time under its provisions as to right of way locations, fully validate the City's title in perpetuity to rights of way over the public domain. Certain conditions were indeed inserted in the Congressional grant relative to the protection of the beauties of the Yosemite National Park, the rights of the irrigationists in the San Joaquin Valley, and the guaranty of adequate speed in hydro-electric power development on the aqueduct line. All of these conditions have been accepted by the City and the project has been so designed as to give them full effect.

Rights of way over privately owned lands have been

fully acquired in the Mountain Division and will be purchased over other divisions as fast as funds become available.

Bond Issue:

The validity of proceedings relating to the authorization, issuance and sale of the Water Bonds, Issue of 1910, from the proceeds of which the project is being constructed is confirmed by the following letter from Honorable John C. Thomson, bond lawyer of New York City, who is the City's legal adviser in all bond matters, and an authority of national reputation:

December 9, 1918.

The Board of Supervisors
of the City and County of
San Francisco, California.

Dear Sirs:—

CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA,
WATER BONDS, $45,000,000.

At your request I have examined into the validity of an authorized issue of $45,000,000 Water Bonds of the City and County of San Francisco, California, to be dated July 1, 1910, to be payable $1,000,000 thereof ten years from date of said bonds beginning with the lowest numbers, and $1,000,000 thereof of the next higher numbers on the same day in each succeeding year until all of said bonds shall be paid, to be of the denomination of $1,000 each, to be numbered from 1 to 45,000 both inclusive, and to bear interest at the rate of four and one-half per centum per annum, payable semi-annually January 1 and July 1. I have examined the Constitution and statutes of the State of California and certified copies of proceedings of the Board of Supervisors of said City and County authorizing the issuance of said bonds, also the form of said bonds as contained in the said proceedings.

It is my opinion that the issue of said bonds has been authorized in accordance with the Constitution and statutes of the State of California, and that when said bonds shall have been signed by the Mayor and Treasurer of said City and County of San Francisco, countersigned by the Auditor thereof, the corporate seal of said City and County affixed thereto attested by the Clerk of the Board of Supervisors, the coupons bearing the engraved or lithographed signature of said Treasurer, and when said bonds shall have been sold in the manner prescribed by law at not less than par and accrued interest to date of delivery, and duly delivered and paid for, said bonds will constitute valid and legally binding obligations of said City and County of San Francisco, California.

Of the above total authorized issue of $45,000,000, bonds to the amount of $5,825,000 have heretofore been sold and delivered and the final opinions of Messrs. Dillon & Hubbard, Messrs. Dillon, Thomson & Clay and myself approving the validity of said bonds have heretofore been given.

Very truly yours,
JOHN C. THOMSON.

FINANCIAL STATUS OF PROJECT

The Hetch Hetchy project is being financed through the sale of water bonds, Issue of 1910. The total authorized present issue is $45,000,000 of 4½ per cent bonds, of the par value of $1,000 each. Maturities range from 1922 to 1964. Of this authorization a total of $13,845,000 had been issued and sold on January 21, 1920, leaving $31,155,000 for sale at the Treasurer's office.

The following schedules show the maturities of the bonds on sale at the Treasurer's office as well as those of the bonds which have not yet been offered.

Supplementing this table there has been added a general statement of the bonded debt and assessment roll of the City and County of San Francisco as of December 1, 1919, which it is believed will be found of general interest.

All proceedings for bond sales are passed upon by John C. Thomson, Esq., Attorney at Law, of New York City, and his certificate as to the validity of the bonds is furnished all purchasers upon request.

SCHEDULE SHOWING AMOUNTS AND MATURITIES OF UNSOLD WATER BONDS.

Date of Maturity	Amount on Sale at Treasurer's Office as at Jan. 21, 1920	Date of Maturity	Amount on Sale at Treasurer's Office as at Jan. 21, 1920
1922	$492,000	1944	705,000
1923	505,000	1945	705,000
1924	505,000	1946	705,000
1925	505,000	1947	705,000
1926	505,000	1948	705,000
1927	505,000	1949	705,000
1928	505,000	1950	705,000
1929	505,000	1951	750,000
1930	705,000	1952	915,000
1931	705,000	1953	915,000
1932	705,000	1954	915,000
1933	705,000	1955	915,000
1934	705,000	1956	915,000
1935	705,000	1957	915,000
1936	700,000	1958	915,000
1937	705,000	1959	915,000
1938	705,000	1960	915,000
1939	705,000	1961	915,000
1940	705,000	1962	915,000
1941	705,000	1963	808,000
1942	705,000	1964	705,000
1943	705,000		
			$31,155,000

STATEMENT OF BONDED DEBT AND ASSESSMENT ROLL, CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA.

ASSESSMENT ROLL FOR FISCAL YEAR ENDING JUNE 30, 1920.

A.	Value of property (non-operative) subject to local taxation:		
	Real estate	$297,744,425	
	Improvements	184,756,781	
	Personal property	67,131,472	
	Money and credits	17,180,509	
	Reassessments	3,380	
	Total non-operative rolls		$566,816,567
B.	Value of property (operative) subject to local taxation only to pay principal and interest on bonds sold prior to November 8, 1910:		
	Total value		$146,343,843
C.	Value of property (operative) not subject to any local taxation:		
	Total value		$80,525,354
	Total assessment roll		$793,685,764
	Value of city property (estimated)		100,209,400
D.	Taxes on property, improvements, equipment, rolling stock, etc., owned by the various steam roads operating in the City and County on which valuation has been authorized by the State Board of Equalization:		
	Actual cash due		$378,478

BONDED DEBT AS AT DECEMBER 31, 1919.

	Bond issues 1904 (various improvements)	$2,388,800
*	Bond issues 1908 (various improvements)	14,342,000
**	Geary and Market St. Ry. Bonds	1,476,000
	Polytechnic High School Bonds	450,000
	Exposition Bonds	4,000,000
	City Hall Bonds	8,200,000
	Hospital—Jail Completion Bonds	1,300,000
**	Municipal Railway Bonds	3,300,000
	School Bonds, 1918	313,000
	Gross debt (excluding water debt)	$35,769,800

DEDUCTIONS

Owned by the City, issue 1904	$ 637,600	
Owned by the City, issue 1908 School Bonds	100,000	

SINKING FUND

Taxes have been levied and are in process of collection sufficient to redeem all bonds maturing on or before July 1, 1920, amounting to	1,578,800	
Total deductions		$2,316,400
Net bonded debt exclusive of water bonds		$33,453,400

HETCH HETCHY WATER DEBT.

Total bonds sold		$13,845,000
DEDUCTIONS		
Bonds owned by the City	$ 817,000	
Sinking fund for the redemption of bonds maturing on or before July 1, 1920, amounting to	1,000,000	
Total deductions		$1,817,000
Net water debt		$12,028,000
Amount of bonds sold prior to November 8, 1910, outstanding as at July 1, 1919		$11,057,200
(For payment of which the property in paragraph B is in part liable.)		

COMPUTATION OF PERCENTAGES OF DEBT.
(Water debt excluded.)

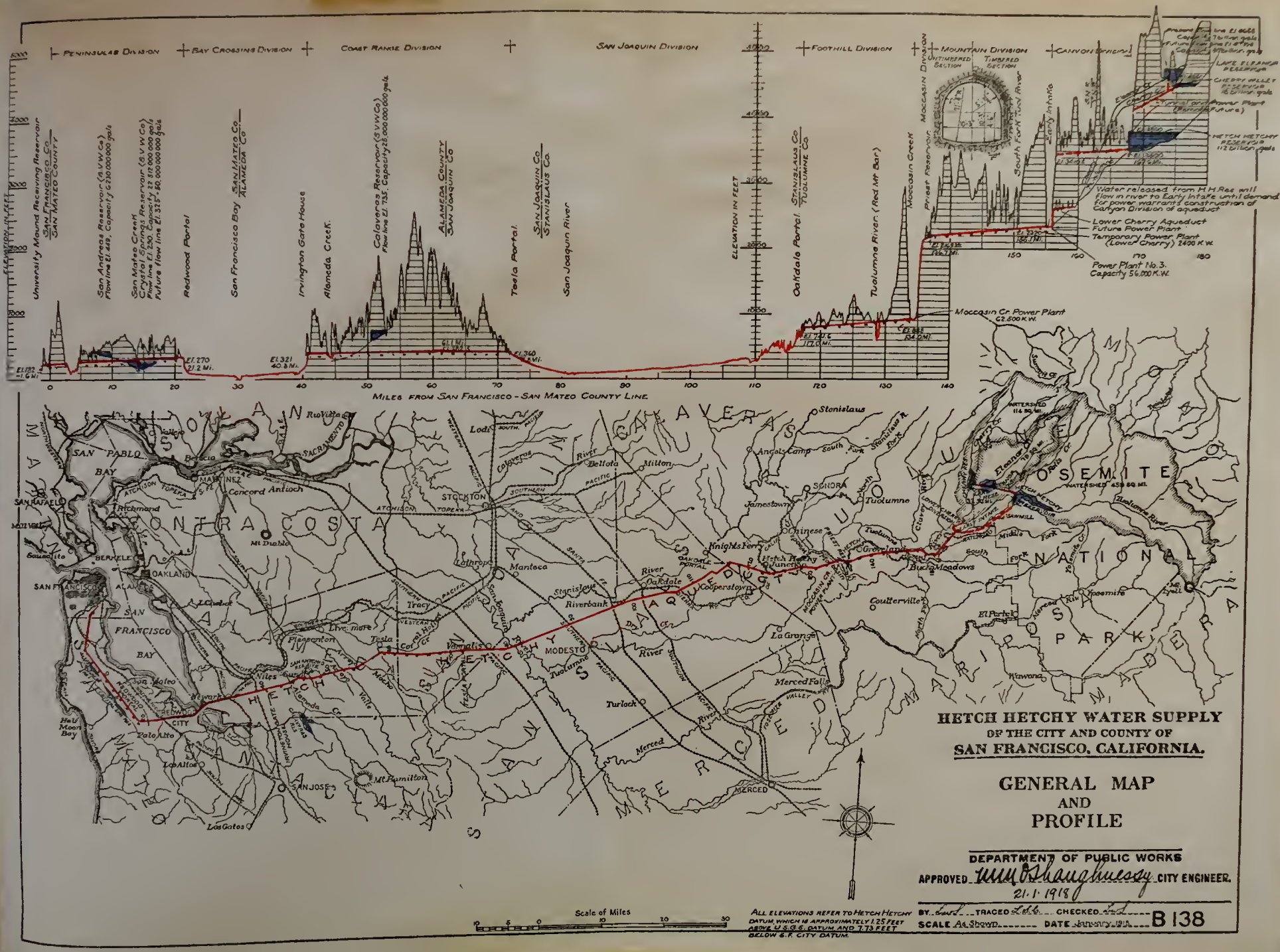
Percentage of $11,057,200 of total assessments, paragraph A and B ($713,160,410)	1.55
Percentage of $22,396,200 to assessment, paragraph A ($566,816,567)	3.95
Percentage of net debt $33,453,400 to assessment, paragraph A ($566,816,567)	5.9

NOTE:—*Includes $5,250,000 invested in a 74-mile auxiliary Water Supply System for Protection, the best in the United States, the use of which in 1914 secured the property owners a reduction of $1,250,000 in the annual insurance premiums of $5,000,000.

**Municipal Railway investment $4,776,000, has constructed 63 miles of single track railway with two fireproof carbarns and 200 street cars, bringing in a gross yearly revenue of $2,600,000 and operating at a profit.

CONTENTS

CONTENTS



HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA.

GENERAL MAP AND PROFILE

DEPARTMENT OF PUBLIC WORKS

APPROVED M M O'Shaughnessy CITY ENGINEER.

21 · 1 · 1918

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SCALE As Shown DATE January 1918

BUREAU OF ENGINEERING
of the
DEPARTMENT OF PUBLIC WORKS
ITY AND COUNTY OF SAN FRANCISCO
CALIFORNIA

Hetch Hetchy Water Supply

By

M. M. O'SHAUGHNESSY
Member American Society, C. E.
CITY ENGINEER, SAN FRANCISCO

OCTOBER 1925

BUREAU OF ENGINEERING

OF THE

DEPARTMENT OF PUBLIC WORKS

CITY AND COUNTY OF SAN FRANCISCO

CALIFORNIA

HETCH HETCHY WATER SUPPLY

BY

M. M. O'SHAUGHNESSY

MEMBER AMERICAN SOCIETY, C. E.

CITY ENGINEER, SAN FRANCISCO

OCTOBER 1925

HETCH HETCHY PROJECT

Foreword

The past three years have been marked with strenuous activity toward the completion of the Hetch Hetchy Water and Power Project of San Francisco, which will be capable of furnishing the water supply for a population of 4,000,000 people when the construction storage works in the high Sierras have been completed.

Five key dams stand completed, two of which—the O'Shaughnessy Dam and the Lake Eleanor Dam, hold back an aggregate amount of water greater than all the reservoirs of Los Angeles and San Diego massed together.

Twenty miles of aqueduct tunnels have been completed in the high Sierras, while at the westerly end of the project Spring Valley water is being passed since September 12, 1925, through the Bay Crossing Aqueduct, 22 miles in length. The right-of-way for the aqueduct measures the width of the State and over this right-of-way the transmission towers have been erected which carry electric energy from the Moccasin Power Plant to the gates of San Francisco.

Since August 14, 1925, the Moccasin Power Plant has been put into service and is now furnishing the greater portion of the power used to light the homes of San Francisco and drive the wheels of its factories. This has been made possible through a contract entered into with the Pacific Gas & Electric Company under which that company is employed as the temporary distributor of San Francisco's power output. The City received for the power delivered in San Francisco during the month of September, $182,426.97, or at a rate somewhat in excess of $2,000,000 annually. On this basis the net revenue from the power, after paying operating expenses, and the $250,000 per annum to be received from the Spring Valley Water Company for the temporary use of the Bay Crossing Aqueduct, amounting to $1,900,000, will pay the interest at 4½ per cent on $42,000,000 of bonds, which is more than is now outstanding on the entire project.

The gap remaining to be completed in the water supply portion of the project is the tunneling and laying of pipe from Moccasin Power House, through the mountains that mark the San Joaquin, Livermore and Santa Clara Valleys, to Irvington terminal. The work in the Foothill Division is now actually under way.

The purpose of this outline is to enlighten the public generally concerning this water and power project, which is the greatest asset that San Francisco possesses, and to these this report is respectfully submitted.

M. M. O'Shaughnessy,
City Engineer.

San Francisco, California, October, 1925.

HISTORY OF HETCH HETCHY WATER SUPPLY

By M. M. O'Shaughnessy, *City Engineer*

EARLY SOURCES OF SAN FRANCISCO'S WATER SUPPLY

SAN FRANCISCO'S earliest water supply was taken from wells within the City, and ten million gallons daily are still obtained from this source. Such wells, however, soon became inadequate, and for a time it was necessary to import additional water in barges from across the Bay, and to distribute it by means of water wagons.

In 1858, a company known as the San Francisco Water Works, instituted a pressure pipe water service, the source being Lobos Creek, which drains the northwesterly portion of the present City. A second company, the Spring Valley Water Works, brought water three and one-half miles from Islais Creek in 1861, and the following year increased its supply by taking from Pilarcitos Creek, 32 miles away. The two companies combined in 1865, under the name of the second, which, in 1903, reorganized as the Spring Valley Water Company.

Under the single management, the sources were gradually added to; San Andreas and Crystal Springs reservoirs in San Mateo County were constructed, and pipe lines were built connecting them to the City.

The Peninsular supply was added to in 1888 by the completion of two submarine pipe lines crossing San Francisco Bay and bringing in water from Alameda Creek. The capacity of the pipe line was increased in 1902, and a booster pumping station added in 1913, bringing the present Spring Valley yield capacity up to about 42 million gallons daily—twenty million from the Peninsula and twenty-two million from the Alameda County sources.

The Spring Valley Water Company acquired, through all those years, over 100,000 acres of land. After a complete survey in 1915, the City Engineer, with the approval of the Railroad Commission, as a basis for purchase by the City, excluded all but 61,560 acres of land as being necessary for water purposes. In San Francisco County there remains for City use 913 acres, in San Mateo 22,817 acres, Alameda County 24,220 acres, and in Santa Clara 13,610 acres.

On the 17th of April, 1922, an agreemnet, sanctioned by the Railroad Commission, was made between the Water Company and the City for the development of an additional 24 million gallons daily by the Company's reconstruction of the Calaveras Dam, Niles Canyon concrete conduit, and 16,000 feet of 44-inch pipe from Niles to Irvington. The City agreed to spend $5,000,000 of the Hetch Hetchy funds in building 22 miles of conduit, consisting of 5-foot diameter pipe—capacity for delivery under Hetch Hetchy conditions of 43 million gallons daily—from Irvington, through Pulgas Tunnel, to Crystal Springs Reservoir. As consideration for the lease of this conduit by the Water Company the City receives an annual

rental of $250,000. Under the same agreement, the City holds an option good until December 31, 1933, to purchase the Water Company's system and the lands enumerated above for $38,000,000.

THE HETCH HETCHY PROJECT IN A NUTSHELL

The Hetch Hetchy Project is one to provide an adequate municipal water supply, evolved by the City and County of San Francisco, after a thorough and comprehensive study of all possible sources. The general plan contemplates the collection and storage of waters of the Tuolumne River and its tributaries near their sources in the Sierra Nevada Mountains, and the transmission of those waters across the San Joaquin Valley and through the Coast Range Mountains for delivery to the City of San Francisco and its environs; due advantage being taken of appropriate drops in the conduit routes for the generation of the maximum quantity of hydro-electric power which can be economically developed.

HISTORY

The project had its beginning back in 1901, when the Mayor of the City filed water appropriations on the Tuolumne River and its tributaries, Cherry River and Eleanor Creek. These appropriations were kept alive by preliminary development work until a permit was obtained from the Federal Government for the acquisition of storage reservoir sites situated on public lands within the limits of the Yosemite National Park (not Yosemite Valley). This was granted by Secretary of the Interior Garfield in 1908 relative to lands and waters tributary to the Tuolumne River in the northern part of the Park and twenty miles distant from the Yosemite Valley proper, which latter is drained by the Merced River. Having secured this permit, San Francisco proceeded to acquire, at an expense of $1,915,000, all privately owned lands in the Hetch Hetchy Valley and the rights and holdings of William Ham Hall, John Hays Hammond and others on the Tuolumne and Cherry Rivers and on Eleanor Creek, a tributary of the Cherry. With the accession of the Ballinger administration in the Interior Department, a movement was started by certain coteries of so-called "nature-lovers," and others, to revoke that portion of the Garfield permit relating to the Hetch Hetchy Valley, which was the largest of the proposed reservoir sites. Secretary Ballinger went out of office after having issued an order directing San Francisco to show cause against this revocation. President Taft ordered an investigation and report by a Board of United States Army Engineers, consisting of Colonel John Biddle, Lieutenant-Colonel Harry Taylor and Major Spencer Cosby. This board of engineers examined exhaustively all alternative sources of supply which had been suggested as available for San Francisco's use, including the Stanislaus, Calaveras, Mokelumne, Cosumnes, American, Yuba, Feather, McCloud, Sacramento, Eel, and San Joaquin Rivers, and the local sources of the Spring Valley Water Company. The Army Engineers' report, made to Secretary Fisher, Mr. Ballinger's successor, under date of February 19, 1913, recommended the use of the Hetch Hetchy Valley and the Tuolumne supply as being not only the most available but the cheapest and most economical for the City's use and affording the greatest hydro-electric development possibilities. Previous to the report of this board of engineers, the City had an exhaustive examination of all available sources made by John R. Freeman, an engineer of national repute, associated with the water supplies of Boston and New York. He strongly recommended the Tuolumne source as the best and outlined the scheme of development which, with some necessary modifications, is now being followed.

After taking testimony and examining all reports submitted, Secretary Fisher gave it as his opinion that Congress alone had the power to grant the privileges

sought by the City. After a great deal of argument before Congress, the Hetch Hetchy grant was passed by both Houses and signed by the President on December 19, 1913. This act was framed on the recommendation of Secretary Lane of the Interior Department and Secretary Houston of the Department of Agriculture, and by it Congress (Stats. 1913, p. 242) granted forever to the City rights in 420,000 acres of the public domain.

The water rights have, from their inception, been carefully protected and title to the same is fully vested in San Francisco under the provisions of the Civil Code of California. Antecedent to this, on January 14, 1910, the people of San Francisco, by a vote of 32,886 for and 1,609 against, authorized the issuance of $45,000,000 of bonds for the construction of the project.

Actual work was commenced as soon as the Congressional grant was obtained. Surveys were completed, many miles of wagon road were constructed, a standard gauge railroad 68 miles long was located and built, the floor of Hetch Hetch Valley was cleared of timber, a sawmill was installed and put in operation, diamond drill borings were made at the main damsite and along the line of the tunnel aqueduct, a construction power plant was built, together with a dam at Lake Eleanor, storing nine billion gallons to carry the plant through the dry season, and an aqueduct to supply the plant with water. Twenty-two thousand volt transmission lines connect it with all working points on the tunnel aqueduct, camps and warehouses. Headquarters buildings were constructed, and work has been completed on the Mountain Division, including the O'Shaughnessy Dam at Hetch Hetchy, the Mountain Aqueduct, Priest Dam, power tunnel, pressure pipes, Moccasin Power House, and tower line for transmission of electrical energy to San Francisco as far as Newark.

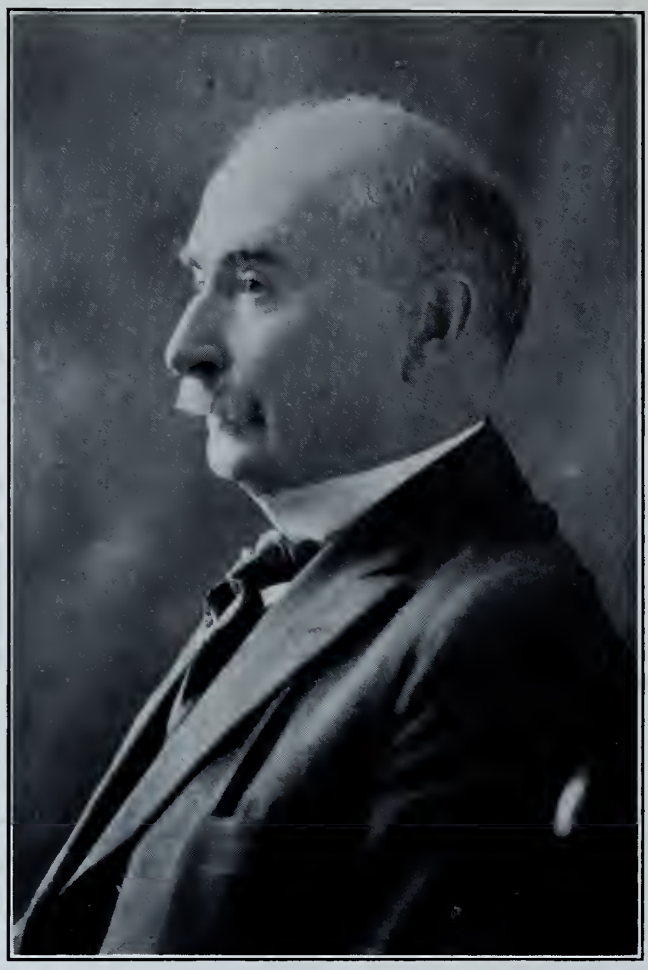
During the period of the war the City carried on work with a force of from 400 to 500 men, with due care always not to interfere with the selective draft or the nation's need for materials and equipment. Progress was necessarily not as rapid as would otherwise have been the case. Sound economic reasoning dictated that the Mountain, or power-generating, division, of the project be completed first, in order that the burden upon San Francisco's taxpayers of paying interest during construction might be reduced by revenue from power at the earliest possible moment. The dominant purpose of the project is, however, water supply, and every effort must be made to complete the water conduits without unnecessary delay in order to remedy the water shortage from which San Francisco has long been suffering.

OUTLINE OF THE PRINCIPAL ENGINEERING FEATURES

The space afforded in this resumé suffices for only a brief description of the principal engineering features of the project. For convenience the work has been divided into ten divisions, known as the Lake Eleanor, Hetch Hetchy, Mountain, Priest, Moccasin, Foothill, San Joaquin, Coast Range, Bay Crossing and Peninsula divisions. Surveys, geological and engineering studies have so far been conducted over the entire work and construction done on all divisions except the San Joaquin and Coast Range.

ORGANIZATION

The Hetch Hetchy development is one of the activities of the Department of Public Works of the City and County of San Francisco. The City Engineer is Chief Engineer of the project, and the Chief Assistant Engineer has direct charge of the work. Two construction engineers, located at Groveland and at Palo Alto, report to the Chief Assistant Engineer. Legal matters are handled by special counsel and rights-of-way by a right-of-way agent.



M. M. O'Shaughnessy, City Engineer

The staff consists of:

GENERAL

M. M. O'Shaughnessy, City Engineer.....Chief Engineer
N. A. Eckart,.....Chief Assistant Engineer

CITY OFFICE ENGINEERS

L. W. Stocker.....Assistant Engineer
R. P. McIntosh.....Hydraulic Engineer
R. J. Wood.....Structural Engineer
P. J. Ost.....Electrical Engineer
E. P. Jones.....Mechanical Engineer

CONSTRUCTION ENGINEERS

L. T. McAfee.....Construction Engineer, Groveland
C. R. Rankin.....Construction Engineer, Palo Alto
L. A. McAtee.....Assistant Engineer, Groveland
J. H. Ryan.....Assistant Engineer, Groveland
A. J. Wehner.....Assistant Engineer, Groveland
L. B. Cheminant.....Assistant Engineer, Groveland
A. B. Johns.....Assistant Electrical Engineer, Groveland

General Office Staff

Robert M. Searls	Special Counsel
Jos. J. Phillips	Right-of-Way Agent
H. W. Kephart	Purchasing Agent

The following are among the experts who have acted as consultants at different times on the project:

Frank G. Baum	Electrical Engineer
Dr. Wm. F. Durand	Mechanical Engineer
Dr. Jas. C. Branner	Geologist
John D. Galloway	Civil Engineer
Professor Chas. D. Marx	Civil Engineer
Professor Charles Wing	Civil Engineer

PROGRAM ADOPTED

In starting any business enterprise it is of the highest importance that the income which is to support the enterprise should commence as early as possible, so that the interest and other fixed charges on the investment shall not be a dead-weight on the investors any longer than absolutely necessary.

In the case of the Hetch Hetchy Project, it required only the construction of the main storage dam and the upper 20 miles of the aqueduct to reach the 1300-foot power drop at Moccasin Creek. Hence the decision was made to concentrate all energy and financial resources on the works above the Moccasin Creek power plant site for the two-fold purpose of developing and protecting our water rights and producing an income from hydro-electric energy that could be applied to reduce the burden of interest and bond redemptions during the later construction of the aqueduct between Moccasin Creek and San Francisco.

With the greatly advanced prices of labor and materials resulting primarily from the World War, exceeding pre-war prices by 70 per cent, and the wider scope of the project as evolved under the Hetch Hetchy grant, and also on account of the necessity of selling bonds at a substantial discount for several years, the completion of the units mentioned will exhaust the funds realized from the $45,000,000 bond issue of 1910. The completion of the aqueduct will require money to be obtained from further issuance of bonds, but the revenue from power sales and from the Spring Valley Water Company will meet, to a very large extent, the interest on the new bonds; so the wisdom of the course adopted is thus apparent.

Construction Begun

Hetch Hetchy Water Supply Contract No. 1, awarded July 8, 1914, covered the grading of nine miles of 22-foot roadway from Mather to Hetch Hetchy, which hitherto had been accessible only by trail. The road was completed in March, 1915.

A diversion tunnel 20 feet in diameter, to deflect the main Tuolumne River, was then excavated in the south wall of the Hetch Hetchy gorge around the damsite. Timber clearing was commenced in the reservoir area, and borings were made at the damsite to determine the depth to bedrock in the river bottom.

Up to the present date, 106 public contracts for all features of the work, aggregating $25,000,000, have been awarded by the Board of Public Works after appropriations have been made by the Board of Supervisors, based on open bidding

on plans and specifications prepared by the City Engineer. There has been no breath of scandal or insinuation of any kind relative to any of these contracts or any other phase of the work.

Railroad

To transport equipment and materials to Hetch Hetchy Dam, the aqueduct tunnels and the power plant, a standard gauge railway was built on grades not exceeding 4 per cent and on curves not exceeding 190-foot radius, extending along the entire upper end of the work in the foothill and mountain divisions. The Hetch Hetchy Railroad, 68 miles in length, connects with the Sierra Railway at Hetch Hetchy Junction, 26 miles from the town of Oakdale, and extends to O'Shaughnessy Dam.

Hetch Hetchy Railroad, Tuolumne River Bridge

Starting at Hetch Hetchy Junction, at an elevation of 935 feet, the route leads across rolling country and descends into the Tuolumne River Canyon to 600 feet elevation. It then follows up the river, crossing it on a steel bridge below Jacksonville. At Moccasin Creek a steep climb begins, and continues until elevation 3070 is attained at mile 26, near the headquarters town of Groveland. From this point east the line follows generally the dividing ridge between the Tuolumne and Merced Rivers. Thence the general elevation increases until at mile 62 the summit is reached —Poopenaut Pass—at elevation 5064. Six miles of continuous descent on a 4 per cent grade complete the 68 miles to Damsite, where the elevation is 3870 feet. The last nine miles of the railroad was built on the roadbed previously graded and used as roadway.

The railroad serves the working points of the 30 miles of main aqueduct east of the Sierra Railway, the Moccasin power development, and the City's sawmill,

some directly, others through short spur tracks, tramways, or motor truck hauls. Haulage from the railroad is generally in the downhill direction.

Snowplow at Mather Station, Hetch Hetchy Railroad

Early Intake from Hetch Hetchy Railroad

The railroad was commenced in 1916—with over 1,000,000 cubic yards excavation, and completed in October, 1917. It was operated from July, 1918, to February, 1925, as a common carrier. Freight rates were on a basis of 12½ cents per ton mile for carload lots for all freight except lumber and livestock, on which commodity rates were established. The basis of passenger fares was 7½ cents per mile.

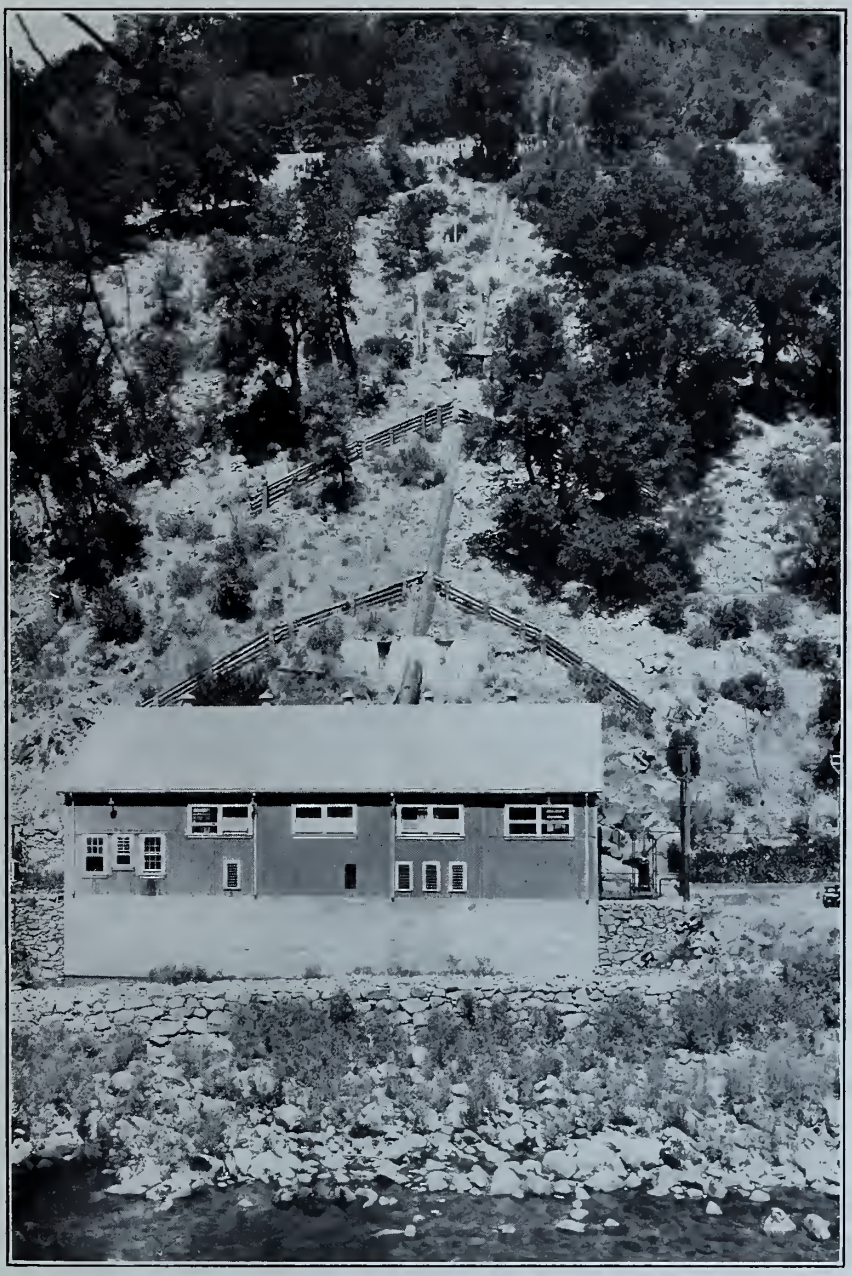
The cost of construction of the railroad was about $3,000,000. The early use of the road enabled the City to complete the O'Shaughnessy Dam in April, 1923, in three and one-half years, and thereby gave San Francisco priority to the flood waters of the Tuolumne River.

The completion of the Don Pedro Reservoir by the Turlock and Modesto Irrigation Districts necessitated the relocation of the Hetch Hetchy Railroad at the Six Bit Gulch crossing, the old trestle at this point being four feet below the flow line of the reservoir. The trestle was replaced by a nine-span plate girder bridge, 585 feet long, 15 feet higher in elevation than the old trestle. The reconstruction of this bridge and the relocation of adjacent stretches of track were made on request of, and were paid for, by the two irrigation districts.

Sawmills

Sawmill machinery was purchased in August, 1915, and a sawmill erected at Canyon Ranch, five miles from Hetch Hetchy. After six million board feet of lumber had been sawed at this location, the supply was exhausted and the sawmill moved to Mather. At Mather it continued to operate until the winter of 1923-1924, when, having served the needs of the present construction, its operation was dis-

City Sawmill at Mather Station, Hetch Hetchy Railroad



Construction Power House at Early Intake. General view showing forebay flume, penstock and building.

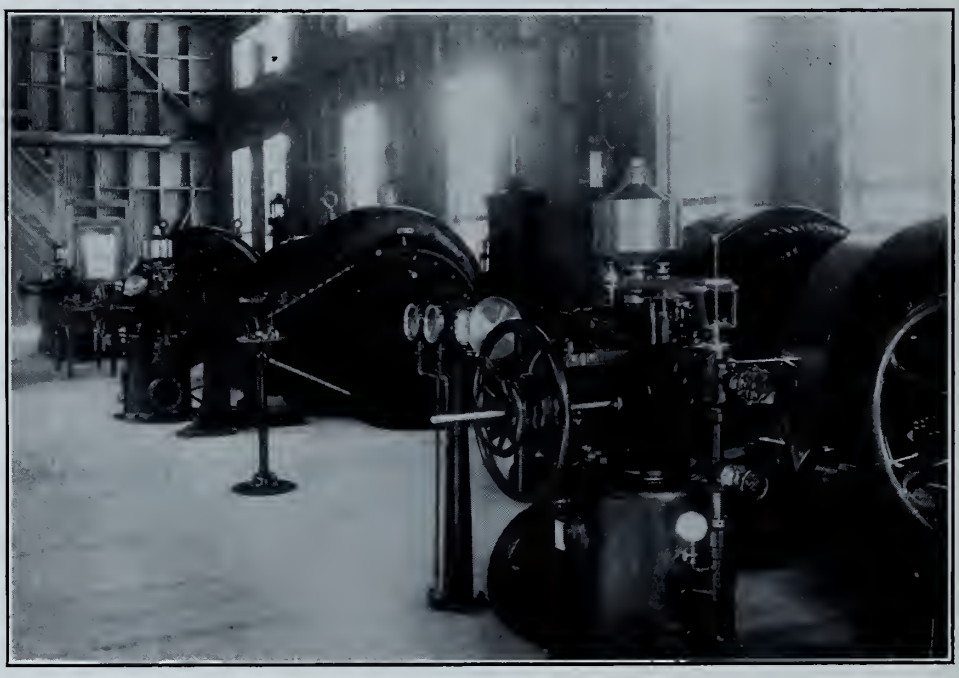
continued. Lumber from the mill was used for concrete forms, camp buildings, flumes, tunnel timbering, and miscellaneous structures. High-grade lumber, such as sugar pine and white pine, not required in the City's work, was traded to privately operated mills to advantage for cheaper woods. A total of 21 million feet B. M. was cut.

LOWER CHERRY POWER SYSTEM

To operate construction equipment in the mountains, a 3000 K. V. A. power plant was installed near the mouth of the Cherry River. The construction was commenced in the summer of 1916, and completed, ready for operation, in June, 1918.

Water for this installation is diverted from Cherry Creek into a conduit of 200 second feet capacity, 3.3 miles long, consisting of 1.2 miles of tunnels, 1.1 miles of flumes, and 1 mile of concrete lined canals. The power house contains three turbines, operating under a maximum head of 345 feet, fed by a 42-inch pipe line 530 feet long, each direct connected to a 2300 volt, 1000 K V. A. generator. Power is transmitted at 22,000 volts 11 miles east to O'Shaughnessy Dam and 22 miles west to Moccasin Creek, supplying intermediate substations along the line. Since the completion of Moccasin power plant the Cherry aqueduct has been extended one-half mile to Early Intake Diversion Dam so that the Lake Eleanor water can be passed through the main aqueduct to Moccasin.

This system has furnished power for all the Hetch Hetchy Water Supply activities as required, except the main sawmill drive; and surplus power has been sold to the Pacific Gas & Electric Company through a connection at Priest. Two interruptions of power operation from February 25, 1922, to April 21, 1922, and from February 25, 1923, to March 14, 1923, resulted from landslides carrying away portions of the open concrete lined canal, and one from November 28, 1921, to December 18, 1921, from a shortage of water. Those breaks caused serious loss in



Construction Power House at Early Intake. Interior showing three Pelton Francis turbines direct-connected to 1000 K.V.A. generators

the continuous operation of the work until a dependable outside standby service was connected up. During such interruptions power was drawn from the Pacific Gas & Electric Company system to supply the westerly end of the work.

LAKE ELEANOR

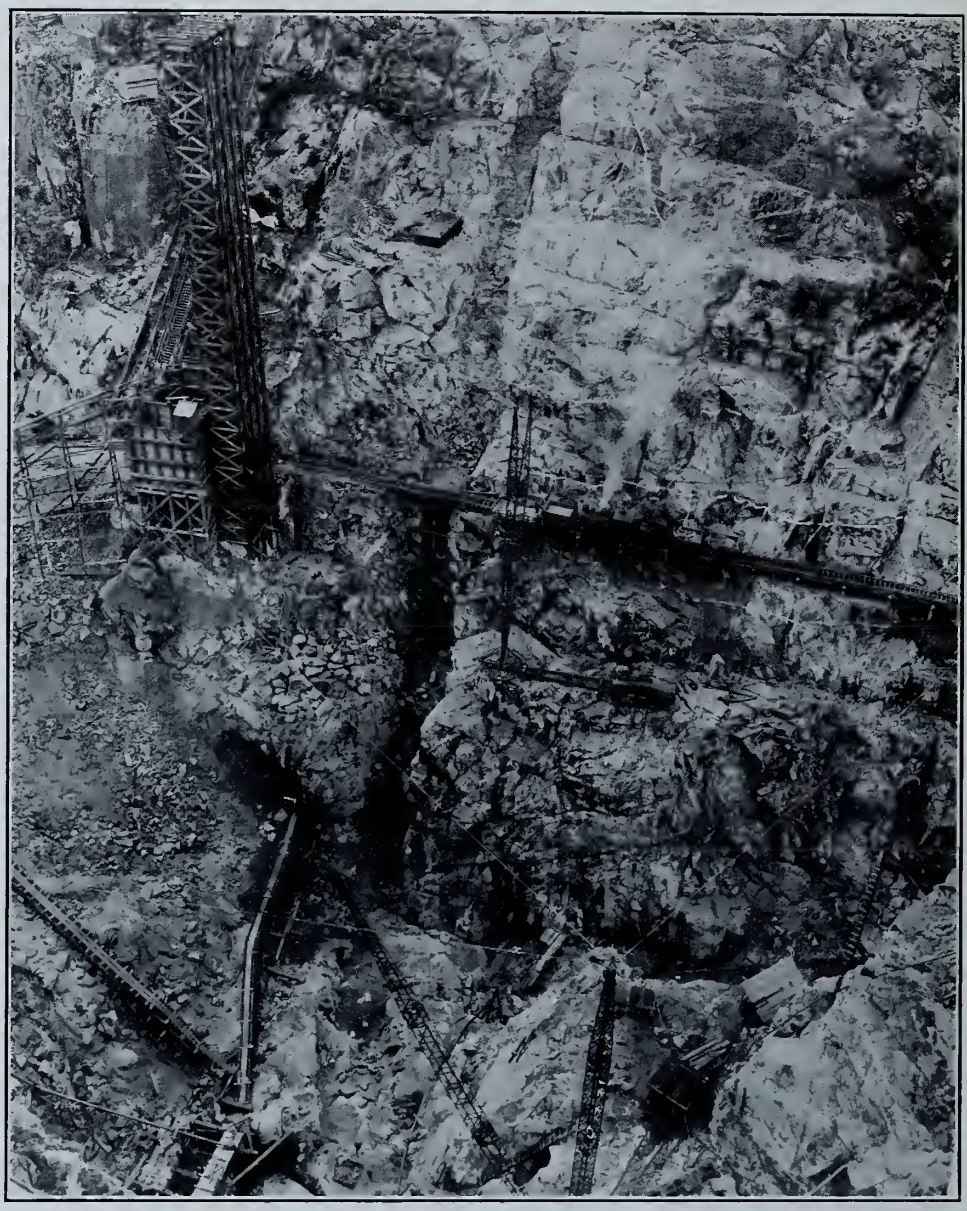
To permit the operation of the power plant during the low water season, it was necessary to develop a certain amount of storage at Lake Eleanor. The construction of Lake Eleanor Dam was commenced in August, 1917. It was put in service in June, 1918. The dam is 1260 feet long and 70 feet in maximum height. It contains 11,640 cubic yards of concrete, heavily reinforced. It is of the buttressed arch type, with several original features developed by the City Engineer's studies. There are 20 arches, each with a span of 40 feet. These arches are on an incline of 50 degrees to the horizontal and are supported by buttresses. The dam is curved in plan. One interesting feature to the engineer is that the cross-section of the arches follows a circular arc on a horizontal plane, and an elliptical arc on a

Lake Eleanor multiple arch dam which impounds 27,800 acre feet

normal plane, which is the reverse of the usual construction heretofore used in this type of dam. Over the entire length of the dam is a reinforced concrete roadway, 12 feet wide.

The stored water is withdrawn through two 24-inch sluice gates, placed on the face of the dam.

The dam was completed late in 1918, but had already been put to use for storage of water to operate the Lower Cherry power plant. The entire cost of the



O'Shaughnessy Dam. Deepest point of excavation for foundation, 118 feet below bed of Tuolumne River. Outline of dam shown by white lines on the rock

structure, including a 12-mile wagon road from Hetch Hetchy costing $28,000, was about $320,000.

The flow line of the reservoir created by the dam is at elevation 4660 feet, and its capacity is about 27,800 acre-feet, or nine billion gallons. This quantity is only a small part of the annual runoff from the Lake Eleanor watershed, and the reservoir is filled each year early in the flood season.

O'SHAUGHNESSY DAM

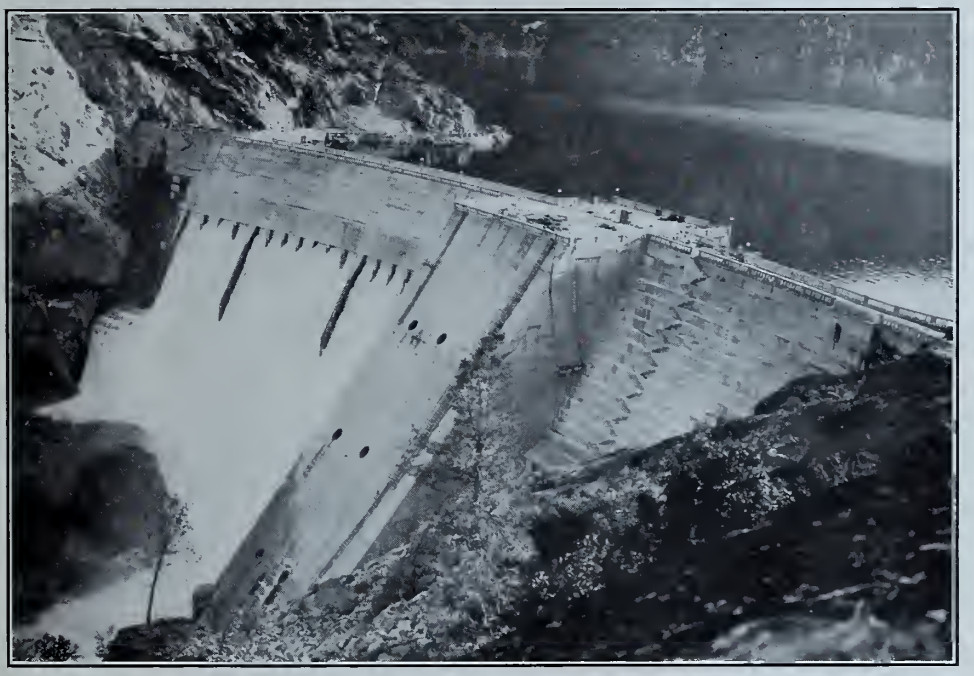
The contract for the construction of the first installment of the O'Shaughnessy Dam across the Tuolumne River at the outlet of Hetch Hetchy Valley, was awarded after open bidding August 1, 1919, to the Utah Construction Company.

The dam is of the arched gravity type—700-foot radius—built of cyclopean concrete (concrete in which are imbedded large blocks of stone ranging in size from about one cubic foot to five or six cubic yards).

When the water supply or electric power requirements demand, the dam will be raised to its ultimate height and thickness. So great is the present-day demand for hydro-electric power, and so constantly is it increasing, that the completion of the last addition will probably be governed by power needs rather than consideration of the water supply.

All foundation work below stream level for the ultimate structure has been completed with the present construction.

When it becomes necessary to add to the reservoir capacity developed by the initial dam, the dam will be brought up to its full ultimate size by adding a thickness of 80 feet on the downstream face of the initial dam and building up 85 feet higher. This will make available 80 feet additional depth of reservoir, and will make the



O'Shaughnessy Dam. The heavy valve section in the center is full thickness for the dam when built to its ultimate height 85 feet above the present crest

lake 300 feet deep at the dam. The total height of the dam above the foundations will then be 430 feet. This is higher than any dam now in existence.

The initial dam has a height above the original stream bed of 226.5 feet, and a maximum height above foundations of 344.5 feet, and contains 398,516 cubic yards of concrete. The length on the crest is 605 feet and the thickness on the crest is 15 feet. The thickness of foundation is 298 feet. The present wasteway consists of 18 spillways of the siphon type, discharging over the downstream face of the dam.

The floor of Hetch Hetchy Valley has been cleared of timber, in order to protect the impounded waters from contamination due to the decay of submerged timber.

Valves for Outlet System

Valves to control the discharge of water for irrigation and domestic use through the dam as required, have been installed at various levels. Openings, designated as supply pipes, supply wells, and discharge conduits, have been cast in the concrete as the structure was built.

The valves consist of the following:

Six 5-foot balanced needle valves;
Six 3-foot balanced needle valves;
Six 47-inch by 90-inch slide gates;
Six 33-inch by 42-inch slide gates.

The valves and their appurtenances comprise over two million pounds of metal of high-grade design, and cost nearly $700,000.

On each opening through the dam there are two controls. The water is admitted through the hydraulically operated slide gate to the supply well and from there the required flow is regulated and discharged by the balanced needle valves. These valves are of the latest type of hydraulically balanced valve which permit manual control of a plunger weighing five tons, under a high head of water. The water discharges in an annular ring surrounding the plunger.

The six 5-foot balanced valves and the six 47-inch by 90-inch slide gates are installed in the main portion of the dam, being set in the concrete as the structure advanced. Three of the 3-foot balanced valves are installed on the lower side of the dam at elevation 3625, in a special valve house, and have three 33-inch by 42-inch gates installed in the dam in connection with them. Three 36-inch needle valves and three 33-inch by 42-inch slide gates are installed in the concrete plug in the diversion tunnel and permit draining the reservoir to its lowest levels. All sluice gates can be made accessible for repairs by closing the inlet tunnels by means of steel shutters in concrete slots.

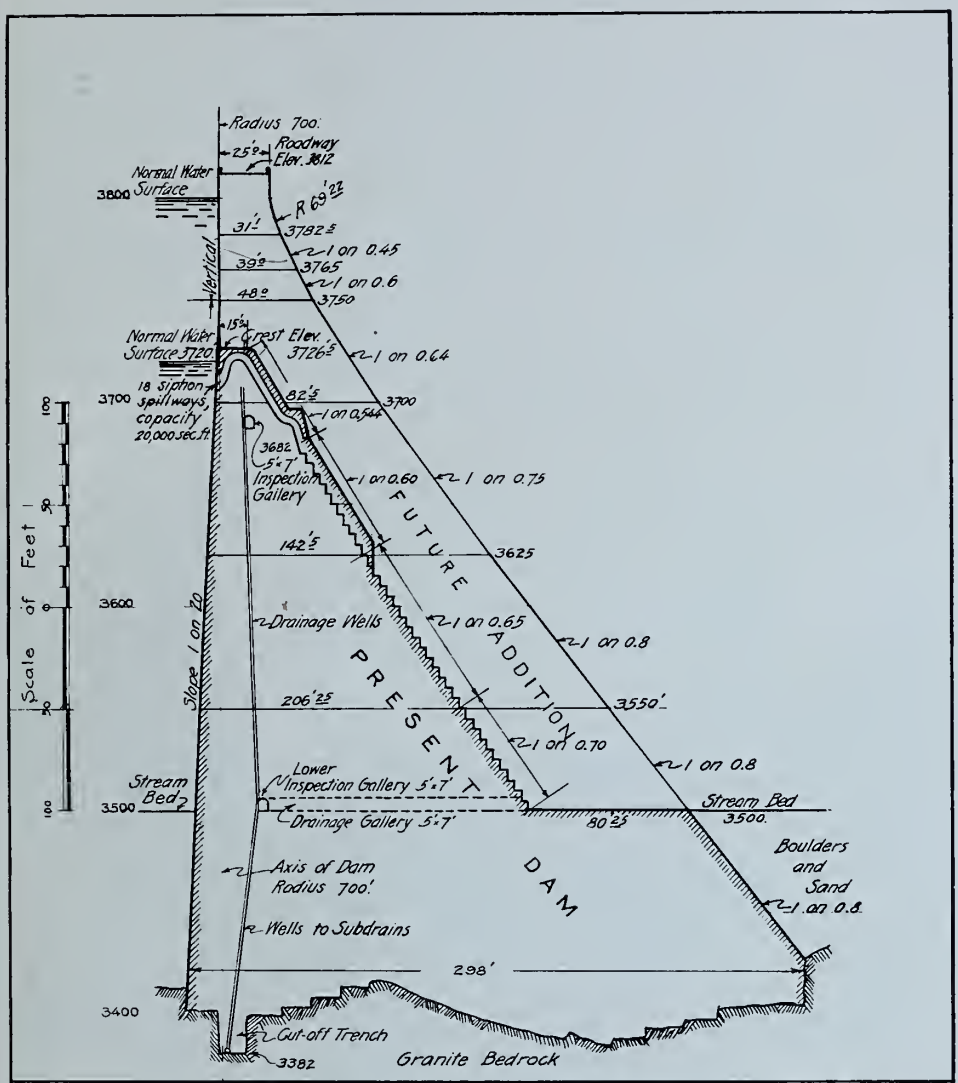
Spillway

The temporary spillway of the initial dam consists of 18 siphons, each 4 feet by 10 feet at the throat, and placed in three series at slightly different levels. The siphon openings are heavily reinforced with steel. Each siphon has a capacity of approximately 1,000 cubic feet per second. The spillway has operated successfully since May 25, 1923, when the reservoir first reached its flood limit. The water discharging from the siphons down the steps on the back of the dam forms a waterfall of imposing appearance.

It is the plan, on the final completion of the dam to full height, to bypass the floods through canals and tunnels at either end past the abutments of the dam so as to clear the structure altogether, and plug the existing siphons with concrete.

Roadway on Dam

The top of the dam is finished with a 17-foot roadway, on the sides of which are placed precast concrete railings, which add an artistic finish to the structure. A concrete girder bridge connecting the dam to the Eleanor road harmonizes with the main structure. The east abutment of the bridge is on roller bearings to provide adjustment to meet temperature changes and consequent movement in the arched dam.



HETCH HETCHY WATER SUPPLY OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA.

O'SHAUGHNESSY DAM
AT
HETCH HETCHY VALLEY

CROSS SECTIONS SHOWING PRESENT AND FUTURE DAMS.

DEPARTMENT OF PUBLIC WORKS. APPROVED W.M. O'Shaughnessy CITY ENGINEER

BY L.S.C. TRACED L.S.C. CHECKED R.A.M.C.

SCALE As shown DATE June 12, 1925.

A 287.

Construction Methods

In order that the foundation of the dam might be constructed in the dry, a rock-filled timber crib dam was built above the location of the main dam, and a concrete backwater dam 800 feet downstream, thus passing the water around the damsite through the diversion tunnel which had been enlarged to 23 feet by 25 feet. Excavation down to 65 feet below streambed was accomplished with steam shovels and dump cars; below that level derricks and skips were used.

At elevation 3439 at the downstream toe, bedrock was encountered and a concrete retaining wall, 31 feet in height, was built, sealing off all seepage into the lowest portion of the foundation. At the upstream toe, on reaching an elevation of 3435 feet, a cofferdam was sunk to bedrock, elevation 3399, and a concrete retaining wall was poured, cutting off practically all seepage into the excavation.

After removing all material overlying the granite bedrock, this was roughened to receive the concrete. A sand-blast was used in places to roughen the glazed and polished surfaces of the pot holes in the water-worn rock formed by pre-historic cascades from ancient glaciers. This provided a clean, rough surface for bonding the concrete.

Concrete was placed with chutes from a wooden, four-compartment hoisting tower, 375 feet high, built on the south side of the canyon. After the forms were removed, a coating of gunite was applied to the upstream face.

During the cold weather period each year from December to March, a heating

Hetch Hetchy Reservoir. View east showing central three miles of reservoir. Kolana Rock on right, rises 1800 feet above floor of valley

plant, consisting of a large steam boiler and circulating pipes, was installed to prevent the concrete from freezing.

Large stone, or plum rock, was placed in the cyclopean concrete to an amount not exceeding 8 per cent of the mass.

Rock for concrete was crushed in a plant located on the valley floor upstream from the damsite. Sand was excavated about three miles upstream from the damsite and hauled to the work on a 3-foot gauge construction railroad, with ten locomotives, and there screened, stored and reconveyed to the mixers. Plum rock was taken from the talus slopes on the north side of the valley and hauled one mile to the dam on flat cars. Cement in bulk was unloaded from cars on the Hetch Retchy Railroad into a bin above the dam, and conveyed to the mixers by gravity.

Concrete placing began in September, 1921, and finished in February, 1922; 398,516 cubic yards being placed.

The dam was completed in May, 1923. The cost of construction by the Utah Construction Company was $6,121,000. On May 24 the reservoir was completely filled and the siphon spillway began discharging the flood waters.

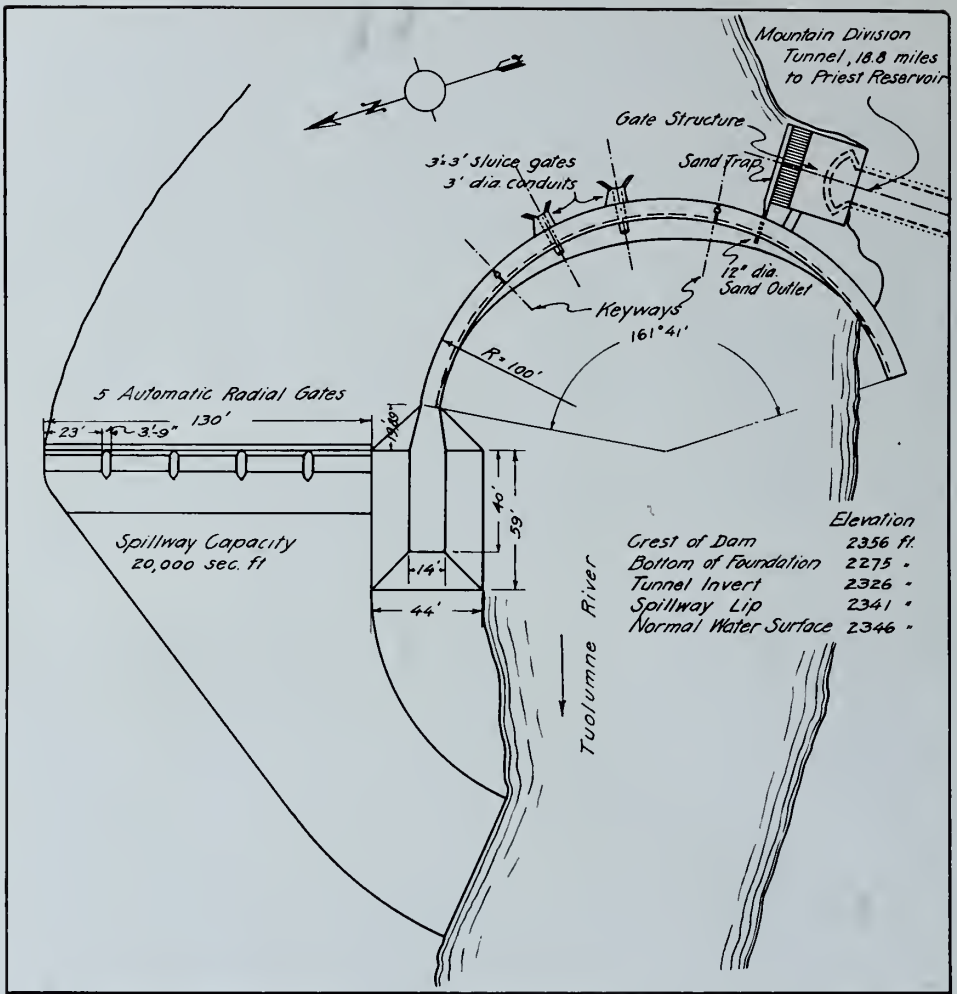
A turbine generator and storage battery were installed in the bypass tunnel to supply power to meet local requirements at O'Shaughnessy Dam when the existing transmission line from Early Intake to the dam is removed.

EARLY INTAKE DIVERSION WORKS

The water released from Hetch Hetchy reservoir flows, for the present, 12 miles down the Tuolumne River to Early Intake Diversion Dam. Eventually, it will flow through a 12-mile tunnel and a power house developing 60,000 horsepower and be discharged above the diversion dam. The water from Lake Eleanor, which now flows down Eleanor Creek, Cherry River, and the Lower Cherry aqueduct about 10 miles to the diversion dam, eventually will be carried in an aqueduct about 11 miles long to a power house in the Tuolumne River Canyon about one mile above Early Intake, where 40,000 horsepower will be generated. The water released from the plant will flow down the river channel with the water from Hetch Hetchy and be diverted into the tunnel aqueduct which begins at Early Intake.

The diversion dam consists of a thin concrete arch 262 feet long and a concrete spillway 130 feet long. On the left bank is the aqueduct intake tower with gates regulating the flow of water for San Francisco's use. Water in excess of that diverted to San Francisco and necessary to supply the Turlock and Modesto irrigation districts will pass over the spillway to flow down the Tuolumne River about 40 miles to Don Pedro Reservoir.

The diversion dam has an upstream radius of 100 feet. Thickness at crest at elevation 2356 is 6 feet, at base 16 feet. Height above river-bed is 55 feet and the base extends 26 feet down to solid granite. On the south, the arch abuts the granite canyon wall; on the north is a concrete block containing 3611 cubic yards. From this block the spillway extends northerly, divided by piers into five sections, each 23 feet long, in which automatic radial gates have been installed, whose function is to maintain the water surface at elevation 2346, or 5 feet above the lip of the spillway. Tunnel invert at inlet is at elevation 2326 feet. A siphon arrangement automatically lowers these gates to pass excess floods and allows them to rise after the flood has subsided. In constructing the arch section of the dam, two vertical openings with keyways 18 inches wide, were left at the points of approximate zero bending



HETCH HETCHY WATER SUPPLY OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA

EARLY INTAKE DIVERSION DAM

GENERAL PLAN

100 50 0 100

Scale of Feet

DEPARTMENT OF PUBLIC WORKS. APPROVED _____ CITY ENGINEER

BY L.B.C. TRACED L.B.C. CHECKED RPMC

SCALE As shown DATE June 4, 1925

A 280.

moment until the dam had taken final set. Then in the extreme cold weather, when the dam had received final set, these keyways were filled with concrete.

The gate tower at the intake is equipped with fixed grillage outside, to catch heavy refuse; and wire mesh, manually operated, traveling screens inside, to catch

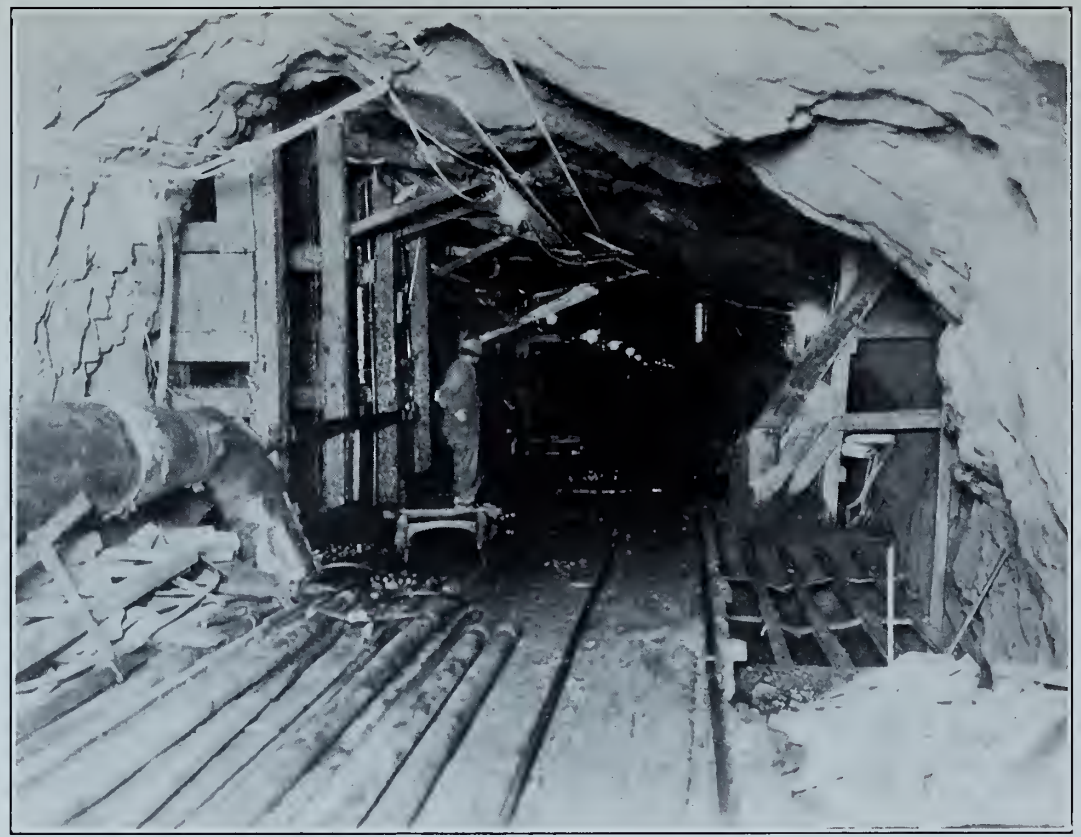
Early Intake Diversion Dam. View up Tuolumne River. Flume on left discharges water from Lake Eleanor and Cherry River. Gatehouse on right is the inlet to the 18.8-mile tunnel to Priest Reservoir. Spillway on left, with automatic gates, bypasses flood waters

leaves and light refuse. Sand chambers in front of the screens discharge through the dam. There are 9 sluice gates, 4 feet by 5 feet, 5 in the lower tier and 4 in the upper. These are set in a thin reinforced concrete arch of 16 feet radius abutting on the rock wall of the canyon. A concrete house covers the operating wheels, screen mechanism, etc., the whole structure being protected from falling rocks from the adjacent mountainside by a reinforced concrete guard wall on the uphill side of the intake. The dam, spillway and gate structure contain 16,564 cubic yards of concrete.

Mountain Division Tunnels

The Mountain Division Tunnels extend 18.8 miles from here to Priest Reservoir. The first half mile of tunnel skirting under the canyon wall is 14 feet 3 inches high by 13 feet 4 inches wide, with top arched to 6 feet 8 inches radius, bottom to 20 feet 5 inches radius, has 166.5 square feet neat excavation, and is unlined, except for a few short stretches. The next seven miles, also unlined, is excavated to 13 feet 6 inches high by 13 feet 4 inches wide, with top arched to 15 feet radius and bottom to 20 feet 5 inches, with neat area 167.8 square feet. This section is interrupted near mile No. 5 by 225½ feet of 9 feet 6-inch diameter riveted steel pipe, which carries the flow across the south fork of Tuolumne River. The pipe is a continuous beam of four unequal spans, the longest being 74 feet across the main channel, and is supported on concrete piers whose reinforcmeent extends into holes drilled in the bedrock. An expansion joint is introduced at the point of contraflexure

Mountain Division Tunnel. Heading showing air drills on bars, muck pile and electrically operated mucking machine

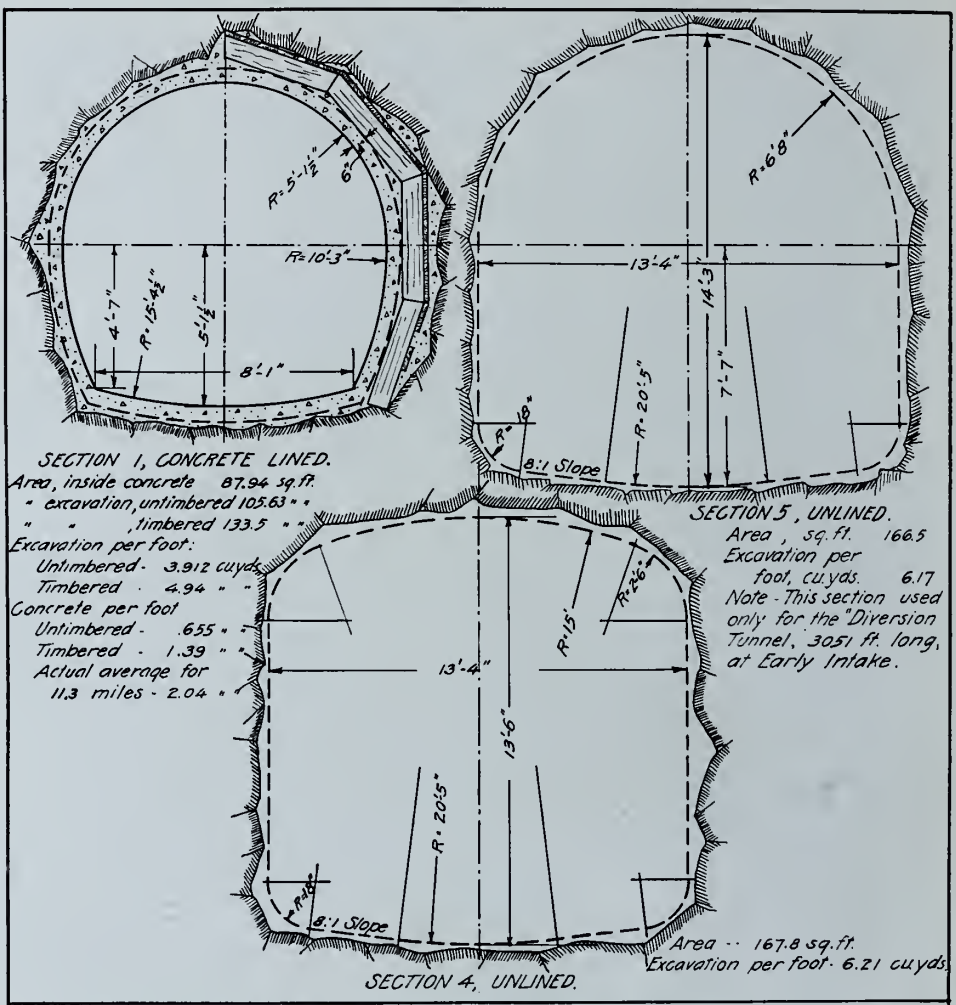


Tunnel station at Big Creek Shaft. Rock pocket at right, ventilating air pipes on left, three compartment shaft on left

nearest the upstream anchor. The pipe is covered with heavy timber to prevent damage from rocks falling from the cliffs above.

The remainder of the tunnel, about 11.3 miles, is lined throughout with 1:2¼:4½ concrete with minimum thickness of 6 inches.

This tunnel is of horseshoe shape 10 feet 3 inches high by 10 feet 3 inches wide, of 87.94 square feet net area inside of lining. The rock encountered consisted of



HETCH HETCHY WATER SUPPLY OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA

STANDARD TUNNEL SECTIONS
USED IN
HETCH HETCHY AQUEDUCT

DEPARTMENT OF PUBLIC WORKS. APPROVED _____ CITY ENGINEER

BY Bac. TRACED Bac. CHECKED RPMc

SCALE 1/4 inch = 1 foot DATE June 9, 1925

A 282

Aqueduct tunnel, showing concrete lining of sides and arch with concrete forms in place

diorite, quartzite, slate and amphibolite schist. The tunnel with a grade of 0.00155, or about 8 feet per mile, has a capacity of 620 second feet.

Excavation was carried on from 12 working faces: one at each end portal, one on each side of the stream crossing, four from two adits and four from two shafts. The first heading was begun at the south fork Tuolumne River crossing, July 7, 1917, proceeding easterly. Big Creek shaft was opened in February, 1918, and tunneling begun from 575 feet below the collar in August, 1919. The shaft was 646 feet deep. Second Garrote shaft, 786 feet deep, was begun in November, 1918, but encountered excessive amounts of water as high as 2,000 gallons per minute, which delayed its completion until December, 1922. The last connection in driving the 18.8-mile tunnel was made between Big Creek shaft and Second Garrote shaft on November 26, 1923.

Muck car trains in the tunnels were hauled by electric storage battery locomotives. Electric mucking machines were used at all headings except while working out from Big Creek and Garrote shafts, which were too small to allow the convenient passage of the electric machines. At these headings smaller air operated mucking machines were used. A spare machine was maintained at each camp to insure continuity of service. Electrically driven air compressors and blowers were used at all the camps. At Second Garrote shaft a steam driven air compressor was maintained for standby service to insure against failure of electric power supply.

The rate of progress varied according to the formation, from 300 to over 700 feet per month. The best record for one month was 776 feet, made from the Priest (west) portal of the tunnel. This established a new United States speed record for hard rock tunnel driving.

Tunnel lining was begun with one plant on March 20, 1923; after April, 1924, two plants were working and completed the lining in May, 1925. The total distance lined is 60,630 feet.

PRIEST REGULATING RESERVOIR

At the west tunnel portal at elevation 2170 the water enters Priest Reservoir, created to provide forebay capacity for the fluctuating demand of the Moccasin power plant. The reservoir was made by constructing an earth fill dam with concrete core wall across Rattlesnake Creek. This forebay reservoir contains 2350 acre feet, or over two days' flow of the tunnel. Priest Dam is 1160 feet long and 145 feet high. Crest width at elevation 2245 is 20 feet. The dam is 660 feet thick at its base and contains 717,283 cubic yards of earth and rock fill and 17,043 cubic yards of concrete in the core wall, which extends 15 feet deep into bedrock. To provide a certain degree of flexibility the core wall is divided into panels 50 feet long by 16 feet high, water stops of 16 gage copper being placed in the joints between panels. Some 27 tons of copper are used in the structure for this purpose.

The embankment consists of rock spoil from the tunnels placed in the up and downstream toes, earth fill placed by hydraulic methods and earth fill placed by dump cars from steam shovel and sluiced into place by water jets. The slope of the upstream face is 2½ to 1; downstream face is 2 to 1 slope except the rock toe, which is 1¾ to 1. The upstream face is riprapped to prevent erosion from wave action.

A concrete lined spillway 40 feet wide, with lip at elevation 2240, protects against overtopping. An outlet and drainage tunnel 6 feet in clear diameter, with inlet at elevation 2120 feet, was driven through the solid rock of the east abutment and lined with 12 inches of concrete. Valves in the tunnel are reached by a vertical,

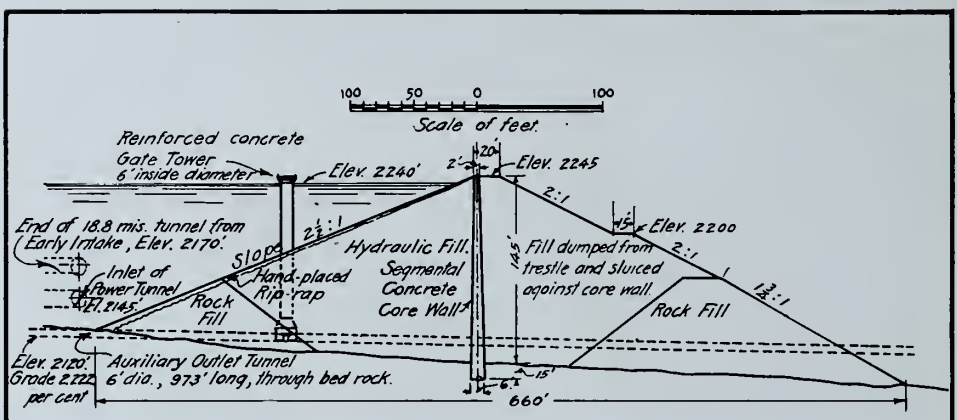
Priest Dam. View down Rattlesnake Creek. Track in left center marks outlet of 18.8-mile tunnel. Power Tunnel begins near sheds in right center

Priest Regulating Reservoir. Dam at left. Gatehouse in upper right is at entrance to Power Tunnel which is 95 feet below high water. Mountain Division Tunnel discharges near house in right center, 70 feet below high water

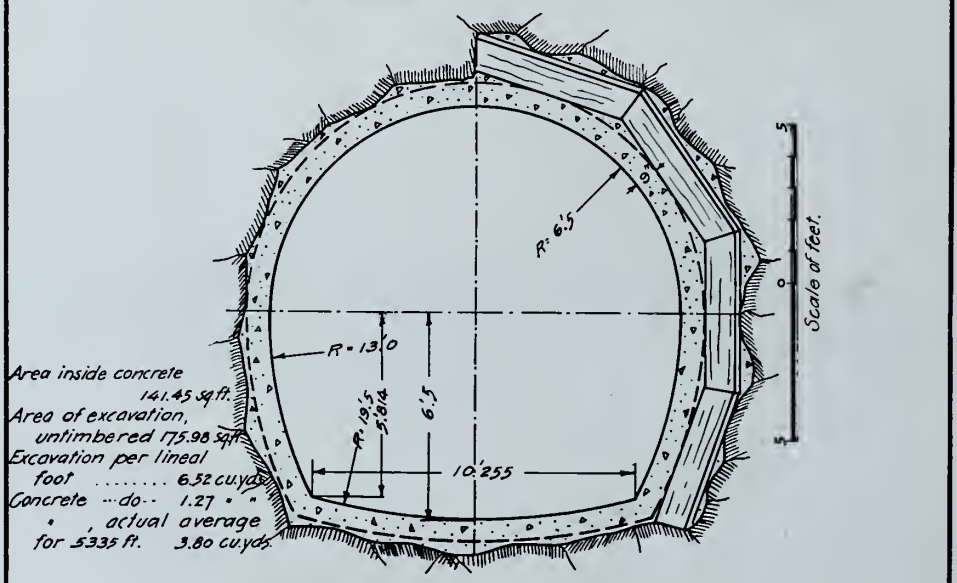
circular concrete tower of 6 feet inside diameter. The tunnel and tower contain 1954 cubic yards of concrete. The dam was begun in January, 1922, and completed in August, 1923.

Moccasin Power Tunnel

Water discharging from the reservoir to the power house enters Moccasin Power Tunnel at elevation 2145 through a concrete control tower, oval in plan,



PRIEST DAM



MOCCASIN POWER TUNNEL.

HETCH HETCHY WATER SUPPLY OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA

PRIEST DAM
AND
MOCCASIN POWER TUNNEL
CROSS SECTIONS

DEPARTMENT OF PUBLIC WORKS. APPROVED ..... M. M. O'Shaughnessy CITY ENGINEER
BY . R.P.S. . . TRACED . R.G.C. . CHECKED . R.P.S. . . .
SCALE . As shown . . . DATE June 12, 1925.

A285.

65 feet by 36 feet, inclusive of semi-circular, precast screen rack projecting into the reservoir. The structure contains 2765 yards of 1:2:4 concrete. Six electrically operated sluice gates, each 6 feet by 8 feet, provide for cutting off water to the tunnel. Manual operation is also possible and steel shutters are provided for isolating any set of gates for repairs, if necessary. Fixed screens with manually operated cleaner prevent fine trash from entering the tunnel.

The tunnel begins as the frustum of an oblique cone tapering from about 19 feet width and height to 13 feet standard section in a distance of 30 feet. The tunnel section is 141.47 square feet with grade of 6 feet per 1000, making its capacity 1240 second feet without excessive loss of head. The minimum thickness of concrete inside of timbering is 9 inches; the concrete averages 3.8 cubic yards per lineal foot. The tunnel extends 5370 feet to the inside wall of a surge shaft 40 feet in diameter, which serves as a manifold for the three penstock pipes, which are imbedded in concrete in tunnels 535 feet long, leading from the opposite side toward the power house.

Surge Shaft

The surge shaft is designed to handle surges of from 35 to 40 feet. The floor is at tunnel grade, elevation 2112, and the height to the rim is 160 feet. It projects 48 feet above the surface of the ground. The walls of this portion range in thickness from 24 inches to 10 inches and contain heavy reinforcement, the maximum of which is two rings of 1½-inch square bars staggered at 7-inch centers. Accumulation of external water pressure below the ground surface which might result from surface runoff, is prevented by a system of porous cement drain tile. The shaft contains 2185 cubic yards of 1:2:4 concrete.

Penstock Pipes

The three penstock pipes, the horizontal length of which is 5349 feet, begin at the wall of the surge shaft, each as the frustum of an oblique cone with large diameter 12 feet 4 inches. The smaller end connects to the 104-inch diameter riveted steel pipe. About 50 feet westerly from the tunnel portal in each line a 104-inch diameter butterfly valve has been installed. The most southerly pipe is dead-ended at the valve pending future extension when two more generators shall have been installed in the power house. The butterfly valves are motor operated and arranged for closing by remote control from the power house. As a matter of precaution the opening control is at the valve only. Two sets of four 8-inch air valves are installed in each line immediately below the valves.

The thickness of pipe plate at the surge shaft is ⅜-inch. At elevation 2070 the diameter reduces to 98 inches and the double riveted lap joints change to triple riveted butt. At a slope distance of 2111 feet the pipes branch each into two 66-inch diameter pipes of hammer forge welded steel with "bumped" joints of enlarged section, reducing obstruction to stream flow of rivet heads. The welded pipes whose slope length is 3469 feet, range in diameter from 66 to 54 inches and in thickness from 7/16-inch to 1 5/16-inch. Immediately before entering the power house the four 54-inch diameter pipes branch each into two 36-inch diameter pipes in which are installed in an arcade of the power house hydraulically operated 36-inch gate valves.

The total weight of pipe is 12,487,709 pounds, the heaviest section of pipe weighing approximately 26,000 pounds. The 30-foot lengths are supported on some 400 concrete piers, or saddles, built in advance of the pipe-laying. At angles, of which there are 20, either horizontal, vertical or combined, the pipes are held securely by concrete anchors, the largest of which contains 839 cubic yards of concrete and 7.64 tons of reinforcing steel. Expansion joints are provided between anchors. At the 98-inch

by 66-inch "Y" branch is a special sliding anchor in which the upper portion, inclosing the pipes, can slide on cast iron plates imbedded in the fixed concrete of the lower portion.

Moccasin Power Plant Penstocks at west end of Power Tunnel. In upper center is the surge shaft where the tunnel divides and pipes begin

MOCCASIN POWER PLANT

This power plant, the largest of the Hetch Hetchy system, uses the full flow of the aqueduct, 620 second feet, dropping from 2240 feet, the elevation of high water in Priest Reservoir, to 924 feet, the elevation of the water wheel nozzles.

The power house, as at present built for four units, is 225 feet long, 98 feet wide and 67 feet high. It is a steel frame building, with massive concrete foundations and with reinforced concrete walls. The architecture is of the California-Spanish style, which is particularly suited to the site. This building houses the generators and low voltage switching apparatus, but the step-up transformers, high tension switches and high tension busses are installed in the rear, out-of-doors, at the easterly side of the building. The busses are carried on a structural steel frame. The 11,000

General view of Moccasin Power Plant showing penstock pipes from Power Tunnel, Power House, beginning of transmission line to San Francisco, operators' quarters, clubhouse and construction camp

volt, 3-phase, 60-cycle current generated, is stepped up to 115,000 volts for transmission to San Francisco. All apparatus, however, is designed for operation at 154,000 volts.

The water wheels were manufactured by the Pelton Water Wheel Company of San Francisco. These are of the double over-hung impulse type and operate at 257 r.p.m. Each has a rated output of 12,500 h.p., or 25,000 h.p. for the unit. The rotating part of each unit weighs 118 tons and can be handled by the 135-ton crane installed in the power house. The static pressure head at the power house is 1316 feet. The water wheel rating is, however, based on an effective head of 1250 feet. The maximum jet diameter is 11 inches. An auxiliary relief needle nozzle is set directly beneath the main nozzle and connected therewith in such manner that it may be operated as a synchronous bypass, or may be set to close automatically to save water.

The generators and exciters were furnished by the General Electric Company. The rating of the generators is 20,000 K.V.A. These generators deliver 11,000 volts directly to the transformers, the arrangement of the power house being such that so far as practicable the generators and the transformers operate together as a unit, provision being made for but one 11,000-volt bus, which can be used to connect any generator to any bank of transformers in an emergency. From this 11,000-volt bus all auxiliary power is taken for use in the operation of the station, and for two 22,000-volt circuits for construction work along the aqueduct line.

The transformers, switchboards and switches were supplied by the Westinghouse Electric and Manufacturing Company. The transformers are single phase, 6667 K.V.A. capacity, with taps which permit of their being operated at either 11,000 to 115,000 volts, or 11,000 to 154,000 volts. They are set out-of-doors in banks of three; complete piping connections are provided for circulating water and for oil filling and filtering. Tracks and transfer cars permit of any transformer being moved into the power house under the crane for repairs.

From the switching station behind the power house, two 154,000-volt circuits will be carried to San Francisco on one double circuit steel tower line. The electric transmission line at the present time has been built as far as Newark on San Francisco Bay, a distance of 98½ miles from the power house; 506 towers are employed in this distance—an average spacing of 1,000 feet. They are placed on the northerly boundary of a 110-foot right-of-way strip, to be supplemented in the future with a similar line on the southerly side. The distance between lines is 24 feet at the top arm, 28 feet at the middle arm, and 24 feet at the bottom arm. The vertical spacing between conductors is 15 feet. The lowest cross-arm is 62 feet above the ground. The conductors from the power house to a point within a few miles of the bay are 397,500 c.m. steel reinforced aluminum conductors. From the point where bay fog is encountered, hemp cored copper conductors are used. These have a circular mil capacity of 345,000, with an external diameter of ¾-inch. At suspension points, 10 units of Westinghouse No. 601 insulators are used, while at dead-end and other points of stress, 12 Westinghouse No. 631 insulators are employed.

Operation of the present two circuits in parallel, as will normally be the case, will permit of transmitting the power generated at the Moccasin plant with a line loss of approximately 8 per cent, and when one line must be taken out of commission temporarily, the remaining circuit will still have capacity to transmit the output of the plant to San Francisco.

Red Mountain Bar Siphon. View showing 9 ft. 6 in. diameter steel pipe incased in concrete, in foreground. Stream diverted and coffer dam constructed preparatory to laying pipe in the east half of channel

FOOTHILL DIVISION

The plan for the aqueduct to San Francisco calls for 17 miles of tunnel in the Sierra foothills below Moccasin Creek, the tunnel being divided into two sections at the Tuolumne River by the Don Pedro Reservoir at Red Mountain Bar. The reservoir is crossed by an inverted steel pipe siphon cased in concrete. This construction was not required for several years to come, but as the river channel at the crossing was to be flooded by the reservoir constructed by the irrigation districts of Turlock and Modesto, the lower portion of the siphon submerged by the lake was constructed in advance of filling the reservoir.

This section, with the ends extending well above the elevation of the dam crest, is of riveted steel pipe, 9 feet 6 inches in diameter and 771 feet long. The thickness of the steel varies from ¾-inch to 9/16-inch. The interior of the pipe is lined with cement mortar 2¼ inches in thickness, leaving the net diameter 9 feet 1½ inches. The pipe is laid on bedrock and is incased in concrete from 18 inches to 2 feet in thickness. The siphon is designed to carry the entire flow of the aqueduct of 400 million gallons per day.

A camp accommodating 100 men, and a plant including tramway, bunkers, etc., were constructed on the west side of the Tuolumne River near the crossing. Excavation was started in the main channel in November, 1922, the water being diverted by means of a cofferdam around the work. This section was rushed with all possible speed. Early fall rains hampered the work and in December, when 12,000 second feet of water passed down the river, a small section of the cofferdam was washed out. After concreting this first section of pipe, the river was turned back into its channel over the pipe and a cofferdam thrown around the east channel. No unusual difficulties were encountered on the remainder of the work and the siphon was completed and tested on June 1, 1923, in time to permit the Modesto and Turlock irrigation districts to close the gates of the Don Pedro Dam and fill the reservoir for that season's irrigation.

SAN JOAQUIN SIPHON

A 45-mile steel pipe siphon is to be constructed as the last stage of the project across the San Joaquin Valley from Oakdale Portal to Tesla Portal, connecting the future Foothill and Coast Range tunnels. To carry the 400 million gallons daily, which will be released from Moccasin power house, several pipes will be constructed in the future as necessary.

COAST RANGE DIVISION

From Tesla portal to Irvington Gate House, a distance of 31 miles, a tunnel 10 feet 3 inches in diameter will be constructed through the Coast Range. It will be broken at one point by Alameda Creek, which will be crossed by a pipe line one-half mile long.

BAY DEVELOPMENT

The water which San Francisco obtains from east of the bay is now limited to about 21 million gallons daily, the capacity flow through one 36-inch pipe. A greater supply from the developed sources in Calaveras Valley, east of the bay, will be made available by the conduit across Dumbarton Strait and westward to Crystal Springs Reservoir. Work now in progress has for its object the construction of a part of the Hetch Hetchy aqueduct, which, as previously mentioned, will be used

temporarily for this purpose by the Spring Valley Water Company immediately upon its completion.

BAY CROSSING PIPE LINE

A 5-foot steel pipe line has been built, extending from a junction with the Spring Valley Water Company pipe line, near Irvington, to the east end of Pulgas Tunnel. The total length of the 5-foot pipe line is 19.4 miles, and the thickness varies from 5/16-inch to 7/16-inch. In firm and dry ground the pipe is buried, except portions crossing gullies near the west end, which are supported on steel trestles resting on concrete piers. Over the marsh lands adjacent to Dumbarton Straits, pipe is laid on timber trestles and is protected from the weather by board covering.

The contract for constructing the pipe line was awarded to the Western Pipe and Steel Company of California on May 18, 1923, for an estimated price of $2,232,000. Pipe laying was begun on October 20, 1923, and all of the pipe has now been laid.

PILE TRESTLE

It was necessary to cross the marsh between Newark and Dumbarton Straits for a distance of about three miles and from the west shore of the bay for nearly one mile. A pile trestle structure was built which carries the pipe about four feet above the surface of the marsh.

Contract and specifications for this were prepared and bids received on April 30, 1924. The contract for the construction was awarded to Youdall Construction Company for the sum of $167,645.

DUMBARTON BRIDGE

Across the shallow portion of Dumbarton Strait the 5-foot diameter pipe is

Bay Development. Five-foot diameter pipe on steel bridge on concrete piers at crossing of San Francisco Bay at Dumbarton Strait

now carried on a steel bridge of 36 spans, each 105 feet long, extending from the west shore of the bay to a concrete caisson at the eastern terminal. It is designed ultimately to carry two pipes, each 6 feet 4 inches inside diameter.

The contract for the steel superstructure was awarded on August 17, 1923, to the United States Steel Products Company, and the contract for the concrete piers and caisson on April 1, 1924, to Healy-Tibbits Construction Company. Construction is still in progress.

The cost under the two contracts will be about $1,465,000.

SUBMARINE SIPHONS

Two navigable channels are crossed by the Bay Crossing Pipe Line, at Dumbarton Strait and Newark Slough. These will be crossed by cast iron pipe 42 inches inside diameter and 2 inches thick. The pipe will be laid in a trench so as to be entirely below the bottom of the bay, and will have flexible joints every 12 feet. The pipe was manufactured by the United States Cast Iron Pipe and Foundry Company. In the future, at the east terminal of the bridge, it will be feasible to sink a shaft and drive a sub-aqueous tunnel to contain the future greater pipes.

PUMP STATION

Near the west shore of Dumbarton Strait a pumping plant has been constructed to supplement the pressure at which the water is, at present, delivered to the pipe line, sufficiently to deliver it into the Crystal Springs Reservoir, 290 feet elevation, through the Pulgas Tunnel.

The station contains three centrifugal pumps, each driven by a 500 horsepower electric motor. With all three pumps operating, the capacity of the pipe line will be about 32 million gallons daily.

When the Bay Crossing Pipe Line is connected with the Hetch Hetchy Water Supply, the use of the Dumbarton pumping station will be discontinued, the gravity head available at Irvington Gate House being sufficient to give the pipe line a capacity of about 42 million gallons daily.

PULGAS TUNNEL

This tunnel, which forms the westerly end of the aqueduct from Irvington to Crystal Springs Reservoir, was completed by Grant Smith and Company in May, 1924, at a total cost of $738,429.23, or $85.11 per lineal foot. It is 8676 feet long, 10 feet 3 inches in height and width inside, and is lined with concrete throughout. All but 240 feet required timbering. Connection to the two portals is made with reinforced concrete pipe 337 feet long. A concrete lined outfall canal 906 feet long, 9 feet wide, extends from end of tunnel to the edge of the reservoir.

Plans for the future provide for extending the aqueduct through San Mateo County to Amazon Reservoir in San Francisco.

CITY RESERVOIRS

The present city reservoirs of the water company have a combined capacity of 125 million gallons, or about three days' domestic water supply, in case the mains should be broken. Prudent policy dictates that a storage of at least 1,000 million gallons should be maintained within the city limits. It is proposed that three great city reservoirs be constructed, known as the Amazon, Glen Park and Balboa Park. Land has been purchased on two of these sites.

Amazon Reservoir, near the county line, in the saddle on the north side of Geneva Avenue between Mission Street and Visitacion Valley, will be the terminal

reservoir of the Hetch Hetchy aqueduct, which will deliver water into it by gravity at elevation 250 feet. The capacity of this reservoir will be 300 million gallons or greater. A tract of land covering 55¾ acres has been selected for this reservoir site and all but 3¼ acres is already in the possession of the city.

Glen Park Reservoir site lies in a canyon just below the Twin Peaks Boulevard and above the old picnic grounds known as Glen Park. At the lower end of the valley there is an excellent bedrock site for a dam of the same general type as the Priest Regulating Dam. A dam 150 feet high will provide storage for 500 million gallons at elevation 385 feet. Over 109 acres of the 184 acres required is already under city ownership.

Balboa Park Reservoir will be constructed on a tract of land in the possession of the Spring Valley Water Company between Balboa Park and Westwood Park, north of Ocean Avenue. The site covers 41 acres. A reservoir with 200 million gallons of water, at elevation 310 feet, may be constructed here.

Glen Park and Balboa Park reservoirs will be filled by pumping from Amazon Reservoir. It has been decided that the most economical elevation at which to receive Hetch Hetchy water in San Francisco is that of the Amazon Reservoir. About 45 per cent of the total ultimate amount of water used in the city may be distributed from this latter reservoir without pumping. The elevation of Crystal Springs Reservoir, 290 feet above the sea, will not permit bringing water by gravity at an elevation materially greater than that of the Amazon Reservoir.

Quality and Quantity of Water.—The water impounded at Hetch Hetchy and Lake Eleanor is of the utmost purity and will always remain so. The total area of watershed aggregates 652 square miles, or about 420,000 acres, all of granite, ranging in elevation from 3500 feet to over 13,000 feet above sea level, and lying almost entirely within Yosemite National Park. The precipitation is mostly in the form of snow, which accumulates during the winter and spring, and whose thawing by the sun's heat reaches its maximum about June. There is no permanent, all-year residence on the entire watershed, which is inhabitable only for the three summer months.

There will be no open canal in the aqueduct, the water being conducted through pipes and tunnels for the entire distance. The water will require no filtration, aeration, chlorination, nor any treatment of any sort.

The Board of Army Engineers, in 1913, reported that there was sufficient water to supply both the reasonable demand of the bay communities and the reasonable needs of the Turlock-Modesto Irrigation District for the remainder of this century. All water measurements are made by the United States Geological Survey.

Finances.—The work was financed up to 1909 by appropriations from the general tax levy.

In November, 1908, a bond issue of $600,000 was authorized by the voters, largely to buy lands and water rights.

In January, 1910, a bond issue of $45,000,000 of 4½ per cent bonds was authorized. Construction has been carried on by these funds. The bonds sold in August to November, 1921, were converted to 5½ per cent, sustaining a discount loss of $2,980,326.55.

The operating receipts of the Hetch Hetchy railroad and power plant, aggregating $1,600,000, have been placed in a special account from which moneys have been appropriated by the Finance Committee of the Board of Supervisors to pay interest on bonds.

On October 7, 1924, a bond issue of $10,000,000 was authorized by the people by a vote of 20 to 1, to continue the aqueduct construction from Moccasin power

house to the edge of the San Joaquin Valley and to begin construction of tunnel from the westerly edge of the San Joaquin Valley to connect with the Bay Crossing pipe line at Irvington.

In about three years it will be necessary to provide an additional $23,000,000 to complete this last tunnel and construct the pipe line across the San Joaquin Valley.

The attitude of the public on the water question was well shown in the elections of 1910 and 1924, where the vote was in each case over 20 to 1 in favor of the bonds.

ESTIMATED COSTS OF VARIOUS DIVISIONS OF THE WORK

Financed from Bond Issue of 1909 and 1910, and General Fund expenditures previous to 1909.

MOUNTAIN DEVELOPMENT

Hetch Hetchy Division

O'Shaughnessy Dam, clearing of Hetch Hetchy Reservoir		$ 7,400,000.00

Eleanor Division

Eleanor Dam, clearing of Lake Eleanor Reservoir		373,000.00

Mountain Division

Early Intake Diversion Dam and spillway and headworks of aqueduct	$ 610,000.00	
Aqueduct tunnels and appurtenances, Early Intake to Priest Reservoir (18.84 miles)	10,100.000.00	
Total		10,710,000.00

Moccasin Division

Priest Dam and Reservoir	$ 930,000.00	
Moccasin Tunnel, from Priest Reservoir to head of penstock lines	1,200,000.00	
Penstock lines	2,000,000.00	
Power House Building, dwellings, school, etc.	1,200,000.00	
Power House Machinery	1,135,000.00	
Transmission Line, Moccasin to Newark	1,623,000.00	
Total		$8,088,000.00

Foothill Division

Red Mountain Bar Siphon		262,000.00

General, Utilities, etc., on Mountain Development

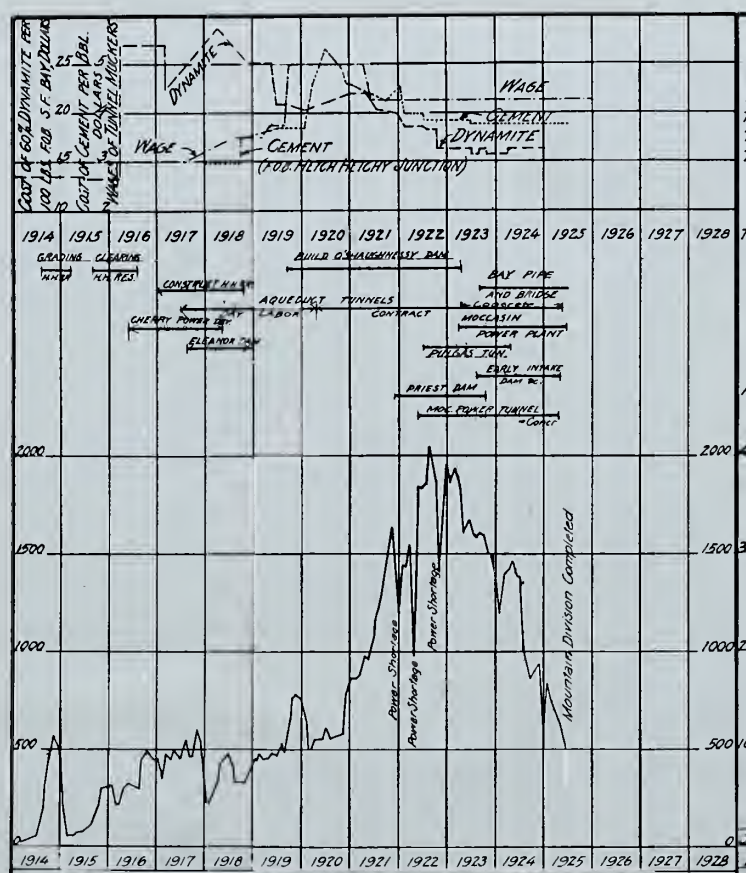
Sawmill construction and operation	$ 556,000.00	
Lower Cherry Power System, construction and operation	1,079,000.00	
Hetch Hetchy Railroad, construction and operation	5,379,000.00	
Munn Sand Plant, Groveland Water Supply, etc	77,000.00	
Hospital, construction and operation	221,000.00	
Miscellaneous Structures, Water Supply at Groveland	196,000.00	
Miscellaneous Roads, Trails, Camps, etc	369,000.00	
Boarding House loss	360,000.00	
Field Engineering and Administration	381,000.00	
Total		8,618,000.00
Total, Mountain Development		$35,451,000.00

Bay Development

Riveted Steel Pipe Line, 60 inches dia	$ 2,408,000.00	
Trestle for Steel Pipe Line	198,000.00	
Submarine Pipe Lines	599,000.00	
Steel Bridge and Piers	1,560,000.00	
Gate Valves, Bay Pulgas Pumps, etc	39,000.00	
Pulgas Tunnel	757,000.00	
Field Engineering and Administration	93,000.00	
City Office Engineering and Administration	42,000.00	
Total		5,696,000.00

General

Administration, Engineering, Legal, etc	$ 1,415,000.00	
Reservoir and Watershed Lands, Water Rights, Rights-of-Way, Payments to U. S. Government, etc	2,020,000.00	
Lands and Rights-of-Way, San Joaquin Division	215,000.00	
Lands and Rights of Way, Transmission Line	117,000.00	
Lands and Rights-of-Way, Bay Development	221,000.00	
Miscellaneous	322,000.00	
Total		4,310,000.00
Total Expenditures		$45,457,000.00
Less credit for receipts from operation of Hetch Hetchy Railroad, Lower Cherry Power System, lumber sales, etc		1,907,000.00
Net total expenditures after deducting credits, which may be still further reduced on final accounting by salvage value of equipment now on hand		$43,550,000.00



HETCH HETCHY WATER SUPPLY OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA

UPPER: GRAPHIC RECORDS OF COSTS OF LABOR AND MATERIALS.
LOWER: GRAPHIC RECORD OF NUMBER OF MEN EMPLOYED.

NOTE: EMPLOYEES IN THE SAN FRANCISCO OFFICES ARE NOT INCLUDED IN THE COUNT.

DEPARTMENT OF PUBLIC WORKS. APPROVED M. M. O'Shaughnessy CITY ENGINEER
BY L.B.C. TRACED L.B.C. CHECKED
SCALE DATE Oct. 15, 1925.

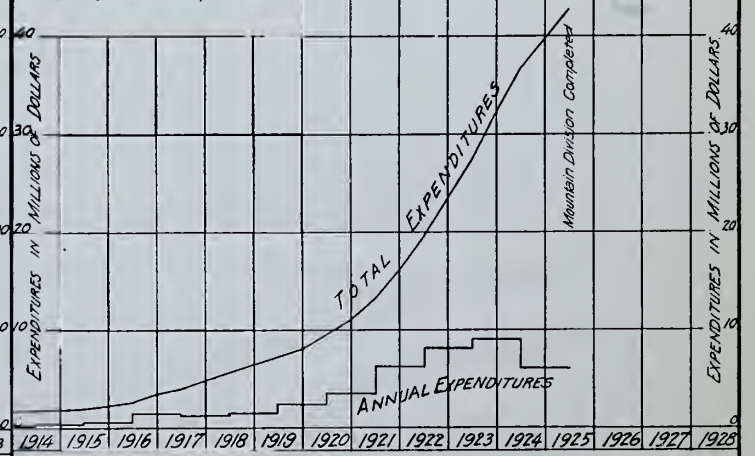
A - 302

EXPENDITURES PRIOR TO 1914

FOR PERIOD	
1900 TO 1906	$ 43,999.39
1907 TO 1910	74,220.54
7-1-10 TO 6-30-12	1,382,287.72
7-1-12 TO 6-30-13	193,543.65
7-1-13 TO 6-30-14	56,255.14

TOTALS	
TO 1906	$ 43,999.39
" JULY 31, 1910	118,219.33
" DEC. 31, 1911	721,434.99
" JUNE 30, 1912	1,500,507.65
" DEC. 31, 1912	1,636,209.45
" JUNE 30, 1913	1,694,051.30
" DEC. 31, 1913	1,721,486.13

FROM	
GENERAL FUND	$ 118,219.93
" 1909 BONDS	603,215.06



HETCH HETCHY WATER SUPPLY OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA

GRAPHIC RECORDS OF
ANNUAL AND TOTAL EXPENDITURES.

DEPARTMENT OF PUBLIC WORKS. APPROVED M. M. O'Shaughnessy CITY ENGINEER
BY L.B.C. TRACED L.B.C. CHECKED
SCALE DATE Oct. 15, 1925.

A - 303

STATISTICS OF HETCH HETCHY WATER SUPPLY OF THE CITY AND COUNTY OF SAN FRANCISCO

I. HETCH HETCHY AND LAKE ELEANOR RESERVOIRS

	—Hetch Hetchy Reservoir—		———Lake Eleanor———	
	Initial	Ultimate	Present	Ultimate
Area of watershed, square miles	459	459	79	183*
Capacity of reservoir, millions of gallons	67,000	113,500	9,000†	71,000†
Acre feet	206,000	348,500	28,000	218,000
Water surface area, acres	1,600	1,940	948	
Square miles	2.5	3	1.5	
Elevation of roadway on dam, feet	3,726.5	3,812	4,661	4,825
Elevation of spillway crest, feet	3,719.75	3,800	4,660‡	4,810
Length of reservoir, miles	7.5	8	3.1	3.2
Width of reservoir, maximum, miles	0.65	0.7	1.0	1.1
Width of reservoir, average, miles	0.33	0.38	0.5	0.7
Depth of reservoir from spillway crest:				
Maximum, feet	220	300	60†	210†
Dam:				
Type of dam	Concrete, gravity section, arched in plan		Reinforced concrete buttressed arch	Rock fill with concrete facing
Total length on crest, feet	605	900	1,260	2,000
Height of crest above stream level, feet	226	312	60	225
Depth from stream level to bedrock, at toe of dam, maximum, feet	(Roadway) 118	(Roadway) 118	Stream bed is solid rock	(Roadway)
Total height of dam, above bedrock, feet	344	430	60	225
Width at top, feet	15	25		25
Width at base, maximum, feet	298	298		
Volume of masonry, cubic yards	398,516	625,000	11,640	
Type of spillway	Siphon	Channel around end of dam	Overflow	Channel around end of dam

*—Includes Cherry watershed above proposed diversion.
†—Lake Eleanor depths and capacities do not include the portion of original lake not available for draft.
‡—With flashboards in place; 4,655 without flashboards.

II. RESERVOIRS FOR FUTURE DEVELOPMENT

	Poopenaut Valley	Cherry Valley	Lake Vernon	Huckleberry Lake	Emigrant Lake
Area of watershed, square miles	473*	114†	40‡	17†	11†
Capacity of reservoir:					
Millions of gallons	10,000	18,500	16,600	17,000	4,600
Acre feet	31,000	57,000	51,000	52,200	14,250
Water surface area:					
Acres	383	1,150	640	800	320
Square miles	0.6	1.8	1.0	1.25	0.5
Elevation of spillway crest, feet	3,468.5	4,550	6,630	7,700	8,700
Length of reservoir, miles	2.3	3.4	2	4	2
Width of reservoir:					
Maximum, miles	0.55	0.8	0.7	0.5	0.3
Average, miles	0.45	0.53	0.5	0.3	0.25
Depth of reservoir:					
Maximum, feet	160	150	105	100	60
Average, feet	81	50	80	65	45
Type of dam	Concrete gravity section	Rock fill	Rock fill or Eleanor type	Rock fill	Rock fill
Length of dam, feet	370	1,060	2,000	520	420

*—Includes Hetch Hetchy watershed.
†—Cherry Valley watershed includes watersheds of Huckleberry and Emigrant Lakes.
‡—Included in Hetch Hetchy watershed.

III. POWER DEVELOPMENT POSSIBILITIES

Location of plant	Early Intake	Moccasin Creek		Early Intake	North Mountain
Source of water supply	Cherry River	Hetch Hetchy and Lake Eleanor		Hetch Hetchy	Lake Eleanor
Aqueduct, type	Flume, canal and tunnel	Pressure tunnel		Pressure tunnel	Canal and tunnel
Aqueduct length, miles (not including pressure pipes)	3.3	19.8		11	7.6
Aqueduct capacity, sec. ft.	200	620		620	200
Forebay, type	Large flume	Reservoir		None	None
Forebay capacity:					
Gallons	1,500,000	800,000,000			
Acre feet	4.6	2,350			
Pressure pipes:		Present	Proposed		
Length, feet	530	5,580	5,580	2,500	5,700
Number of pipes	1	2	3		
Diameter of pipes	3′6″	104″-54″	104″-54″		
Gross drop, feet	345	1,316	1,316	1,100	2,000
Power plant:					
24-hr. average capacity—					
K. W.	3,000	52,500	52,500	42,000	24,000
H. P.	4,000	70,000	70,000	56,000	32,000
Number of generators	3	4	6		
Capacity each machine, K. W.	1,100	17,500	17,500		
Total installed capacity—					
K. W.	3,300	70,000	105,000		
H. P.	4,400	94,000	141,000		

Note: Development of Huckleberry and Emigrant Lakes as reservoirs will make available additional power, the amount of which has not yet been determined.

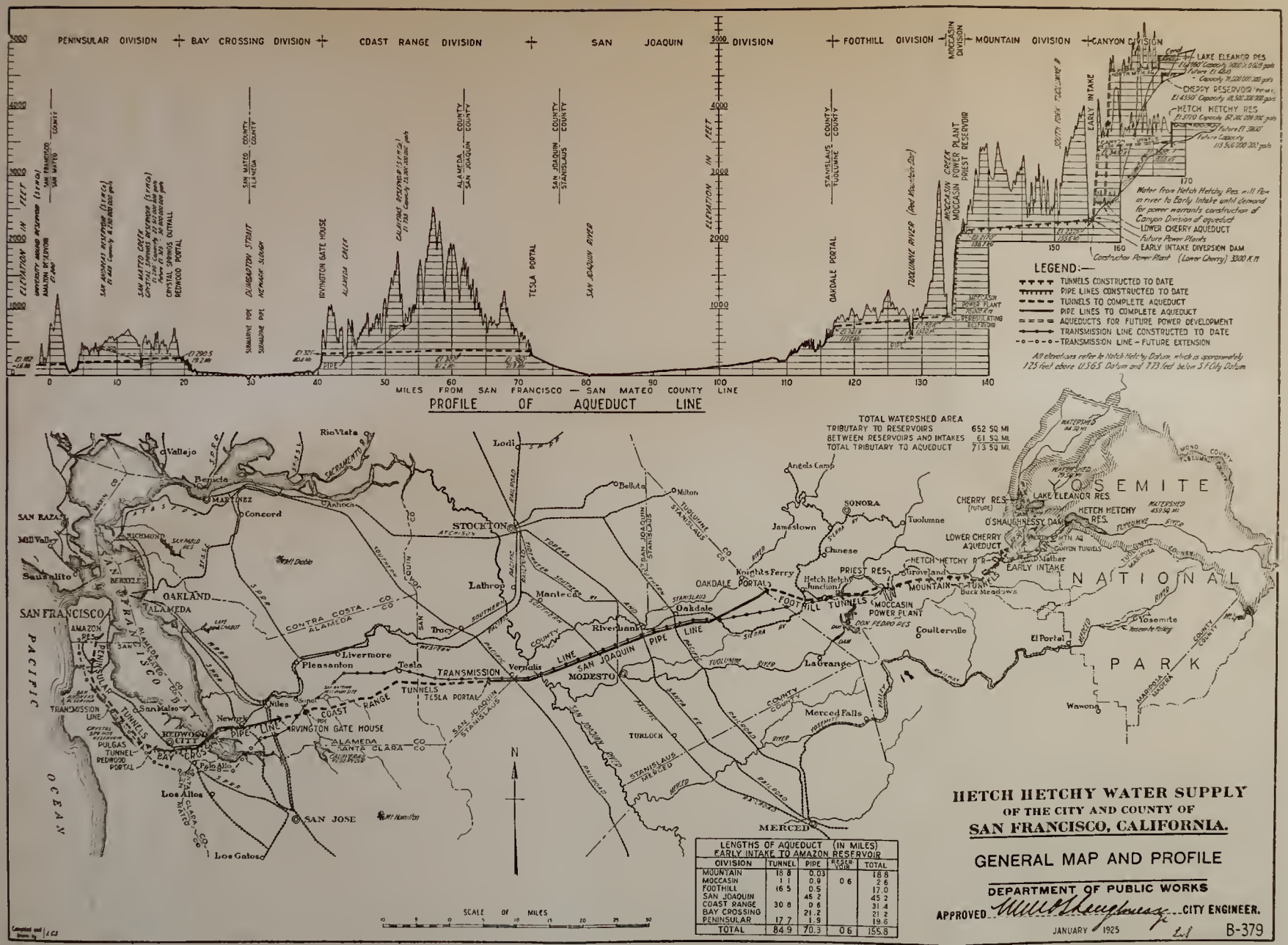
CHRONOLOGY, HETCH HETCHY WATER SUPPLY

Jan. 8, 1900	New Charter in effect.
March 26, 1900	Solicitation of offers of sale of water supplies to City.
Aug. 12, 1901	City Engineer recommends Tuolumne River.
July 29, 1901	Appropriations made on water at Hetch Hetchy and Lake Eleanor by Jas. D. Phelan.
Oct. 16, 1901	Filings of same at Stockton Land Office.
Jan. 20, 1903	Phelan's applications denied by Secretary of Interior Hitchcock.
February, 1903	Petition for rehearing, by Franklin K. Lane, City Attorney.
Feb. 20, 1903	Filings assigned to City.
Dec. 22, 1903	Application again denied by Secretary of Interior.
May 11, 1908	Original applications approved by Secretary of Interior Garfield.
Nov. 12, 1908	Special election authorized construction of Tuolumne System and issue of $600,000 of bonds, to buy lands, etc.
Jan. 14, 1910	Bond election, $45,000,000 bonds authorized by vote of 20 to 1.
Feb. 25, 1910	Order to show cause why Hetch Hetchy should not be eliminated: Secretary of Interior Ballinger.
May 12, 1910	Secretary of Interior requested Secretary of War to appoint Board of Army Engineers to act as Advisory Board.
May 18, 1910	Board appointed.
July, 1912	"Freeman Plan" of Hetch Hetchy development, published and submitted to Army Board.
Sept. 1, 1912	M. M. O'Shaughnessy appointed City Engineer.
Nov. 25 to 30, 1912	Hearings before Secretary of Interior Fisher, attended by Mayor, City Engineer, City Attorney and consulting engineers.
Feb. 9, 1913	Army Board report upholds selection of Tuolumne River as $20,000,000 cheaper than any other system and having greatest power possibilities.
March 3, 1913	Conference: City Engineer with Secretary Fisher.
June 25 to July 7, 1913	Hearings by committee on the Public Lands, House of Representatives.
Dec. 19, 1913	Hetch Hetchy Grant, or "Raker Bill," signed by President Wilson.
July 8, 1914	Bids received by Board of Public Works for Contract No. 1, for constructing a road from Hog Ranch (now Mather) to Hetch Hetchy.
July 21, 1915	Began manufacture of lumber at Canyon Ranch.
September, 1915	Began construction of camp buildings at Hetch Hetchy, clearing of Hetch Hetchy Reservoir site, and construction of Diversion Tunnel.
Nov. 24, 1915	Bids received for construction of Hetch Hetchy Railroad.
Aug. 9, 1916	Bids received for "Drifting Tunnels, Lower Cherry Aqueduct," already begun by day labor.
October, 1917	Hetch Hetchy Railroad operation begun.
May 6, 1918	Lower Cherry Power House began operation.
Aug. 1, 1919	Contract awarded for construction of Hetch Hetchy Dam.
May 3, 1920	Contract awarded for construction of Aqueduct Tunnels in Mountain Division, this work having been carried on so far by day labor.
Fall, 1921	Work begun on Priest Dam.
Fall, 1921	Work begun on Moccasin Power House.
June 23, 1922	Contract awarded for construction of Pulgas Tunnel.
May 18, 1923	Contract awarded for construction of Bay Crossing Pipe Line.
Oct. 7, 1924	Special Election, $10,000,000 bonds authorized to construct Foothill Tunnels and begin Coast Range Tunnels, vote 20 to 1.
Aug. 14, 1925	Delivery of power began from Moccasin Power Plant.

ELEVATIONS OF VARIOUS POINTS ON WATER PROJECT

13,090 ft.	Summit of Mt. Lyell, highest point on watershed.
4,825 ft.	Crest of future Lake Eleanor Dam.
4,810 ft.	High water, Lake Eleanor Dam.
4,660 ft.	Top of present Lake Eleanor Dam.
4,590 ft.	Creek bed at Lake Eleanor Dam.
3,812 ft.	Crest of future O'Shaughnessy Dam.
3,726.5 ft.	Crest of present O'Shaughnessy Dam.
3,500 ft.	River bed at O'Shaughnessy Dam.
3,382 ft.	Lowest point of foundation, O'Shaughnessy Dam.
2,346 ft.	Normal water surface, Early Intake Diversion Dam.
2,326 ft.	Floor of tunnel, Early Intake Diversion Dam.
2,240 ft.	High water, Priest Regulating Reservoir.
2,170 ft.	Floor of tunnel at Priest Portal of 18.8-mile tunnel.
2,145 ft.	Floor of inlet of Moccasin Power Tunnel.
924 ft.	Nozzles of Moccasin Power House.
888 ft.	Floor of Foothill Division Tunnel at Moccasin Creek.
741.6 ft.	Floor of Foothill Division Tunnel at Oakdale Portal.
360 ft.	Floor of Mt. Diablo Range Tunnel at Tesla Portal.
321 ft.	Floor of Mt. Diablo Range Tunnel at Irvington Gate House.
290.5 ft.	Floor of Pulgas Tunnel at Redwood Portal.
250 ft.	Water surface, Amazon Reservoir, San Francisco.

THE JAMES H. BARRY CO.
1122 MISSION STREET
SAN FRANCISCO, CALIF.



LENGTHS OF AQUEDUCT (IN MILES) EARLY INTAKE TO AMAZON RESERVOIR				
DIVISION	TUNNEL	PIPE	RESERVOIR	TOTAL
MOUNTAIN	18 8	0.03		18.8
MOCCASIN	1 1	0.9	0 6	2 6
FOOTHILL	16 5	0.5		17.0
SAN JOAQUIN		45 2		45 2
COAST RANGE	30 8	0 6		31 4
BAY CROSSING		21.2		21 2
PENINSULAR	17 7	1.9		19.6
TOTAL	84.9	70.3	0 6	155.8

HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA.

GENERAL MAP AND PROFILE

DEPARTMENT OF PUBLIC WORKS

APPROVED _____ CITY ENGINEER.

JANUARY 1925

B-379